THE ENGINEERING REVIEW.

Edited by
C. EDGAR ALLEN.

Vol. 10. APRIL, 1904. No. 4. (New Series.)

Tesla's Experiments.

MR. NIKOLA TESLA is known throughout the scientific world as a worker of eminence and of striking originality, whose investigations have in the past helped very materially in the progress of electrical science. His researches are at all times worthy of close attention, and are sure to receive it, even if his speculative conclusions drawn from his experiments may not be universally accepted. Of recent years less has been heard than formerly of Mr. Tesla's work, but it has been generally known that he has been engaged on extensive investigations on the ætheric transmission of electrical energy. Now, however, there are signs that he is ready to give the public the benefit of these investigations, and we may confidently expect soon to have much interesting material for discussion. The honour of having induced Mr. Tesla to break his long silence belongs to the editor of our esteemed contemporary, *The Electrical World and Engineer* of New York, who has succeeded in obtaining a communication for publication in the special anniversary issue of March 5th, 1904. We are the more indebted to that journal, as Mr. Tesla himself states that, but for its initiative, his account of his experiments "might not have been given to the world for a long time yet."

The opening paragraphs of Mr. Tesla's paper are devoted to a description of the surroundings of the place where his experiments have been carried out. The spot selected was a large plateau, two thousand metres above sea level, in the neighbourhood of the Colorado Springs. The air there is remarkably pure, and the senses of sight and hearing become, according to Mr. Tesla, much more acute; thunder-claps at some seven or eight hundred kilometres' distance have been distinctly heard. The site chosen for an electrical research station was the more suitable in that "Colorado is a country famous for the natural displays of electric force." Lightning discharges are very frequent and sometimes extremely violent. "On one occasion," says Mr. Tesla, "approximately twelve thousand discharges occurred in two hours, and all in a radius of certainly less than fifty kilometres from the laboratory."

In these surroundings Mr. Tesla set himself to determine the electric potential of the earth, and to study its periodic and casual variations. He constructed transformers of special design to receive the natural electrical vibrations. The variations of potential set up surgings in the primary circuit, which had its terminals connected respectively to the ground and to an elevated terminal of adjustable capacity. The effect of these surgings in the primary was to induce currents in the secondary circuit, which included a sensitive device controlling a recorder. By

this means the electrical state of the atmosphere could be kept constantly under observation.

The most interesting part of Mr. Tesla's communication is that which deals with his discovery of stationary waves set up by an electrical disturbance. On the evening of the 3rd July, 1899, a violent storm occurred in the west, and after spending much of its force among the mountains it was driven rapidly across the plains. As this recession took place Mr. Tesla's recording apparatus gave fainter and fainter indications until they finally ceased altogether; but in a short time they began again, growing steadily stronger till they reached a maximum and then steadily falling off once more to zero. Again and again this cyclic process was found to be repeated until the storm, which had been steadily receding, had reached a distance of about 300 km. from the observing station; and even at greater distances the same effects were produced on the recorder with undiminished force. This most interesting phenomenon, which has been frequently confirmed since that date by Mr. Tesla and his assistants, shows that stationary waves were set up by the source of disturbance, and that as the source moved away the receiver at the laboratory came successively under nodes and loops. "Impossible as it seemed," adds Mr. Tesla, "this planet, despite its vast extent, behaved like a conductor of limited dimensions. The tremendous significance of this fact in the transmission of energy by my system had already become quite clear to me. Not only was it practicable to send telegraphic messages to any distance without wires, as I recognised long ago, but also to impress upon the entire globe the faint modulations of the human voice: far more still, to transmit power in unlimited amounts to any terrestrial distance and almost without any loss."

It is at this point, where he passes on at once from an ascertained fact to speculate upon wondrous future possibilities, that Mr. Tesla becomes unsatisfactory. This jumping into the regions of the unknown is somewhat characteristic of him and of his work in recent years, but he fails to make us share his enthusiasm, and to make us feel that these flights of fancy are justified. In this particular paper he goes on to tell us that he at once set himself to improve his magnifying transmitter and the means of individualising and isolating messages. No details are given, but he tells us that much has already been done to make his system of "World Telegraphy" commercially available; and he is at present designing a power-plant for the Canadian Niagara Power Company, which will distribute ætherically ten thousand horse-power under a tension of ten million volts.

We certainly wish Mr. Tesla every success in his great work, but we have doubts as to the stability of the foundations on which his speculations are based. A man may certainly achieve valuable practical results even if his theory be faulty; but we should prefer to see him start with a correct theory. We cannot discuss at length Mr. Tesla's views on this subject, nor is it desirable to do so until more of his work has been given to the public; but we would point out that the conclusion that the earth acts as an ordinary conductor of limited dimensions scarcely justifies the subsequent conclusions, nor is it in itself new. The phenomenon of the stationary waves produced by the thunderstorm is extremely interesting and the experiment is a beautiful one, but, if we mistake not, the idea of the earth acting as an ordinary conductor has already been adopted in some theories of wireless telegraphy, and no one has considered such a thing as "seemingly impossible." Mr. Tesla claims that his system is entirely different in action from those used for Hertzian or electromagnetic radiations, but until it is more fully disclosed we must reserve our judgment on this point. We shall certainly await with interest the publication of Mr. Tesla's most recent work in full detail, and even if we should find we cannot accept all his theories and conclusions, we are confident that the practical experiments will be worthy of close study.

The Liverpool and Southport Electric Railway.

THE inauguration of the operation of the Liverpool and Southport section of the Lancashire and Yorkshire Railway by electricity, which took place so successfully on Saturday, March 12th, is an event of considerable importance in the history of British railways. Although so much has been done in recent years in the development of electric traction in this country, that development has been confined almost entirely to the introduction of new schemes—tramways, light railways, and underground "tubes"—while the existing railways have continued as before to use steam propulsion. At last, however, the conversion of a main-line railway from steam to electric traction is an accomplished fact, and the operation of this line on the new system will teach many lessons by which other railways will profit, and will perhaps help to remove some of the difficulties at present standing in the way of the complete supersession of the steam locomotive.

The electrical equipment of a line such as that we are now considering involves a large amount of labour, and requires considerable engineering skill; and it is especially gratifying to find that the work has been carried out by a British firm, and that the engines and generators and other electrical apparatus are almost entirely of British make.

A general outline of the equipment of the Liverpool and Southport Railway appeared in our February issue, and we may therefore pass over the engineering features of the scheme, and consider only the economic aspect of this change. To railway managers the most important matter will be the cost of operation under the new *régime*, and the effect upon traffic returns. It is, of course, much too early yet to come to definite conclusions on these points. We must await actual results; but we feel confident that the directors will find ample justification for their enterprise when these results are put before them. The effect of the electrification of the Manhattan elevated railroad was to reduce very materially the percentage ratio of working expenditure to receipts, and although that line is not analogous to the Liverpool and Southport line, we believe that the same result can be obtained here. The service of trains will, of course, be greatly improved, as there will be local trains every ten minutes from Liverpool to Hall Road, and from Liverpool to Southport local trains every twenty minutes, and an express train once every hour. This should certainly lead to an increase of traffic with a corresponding increase in the money returns. There is, however, little use in speculating on these matters when, by simply waiting, we can have actual figures. The really important matter is the actual conversion from steam to electricity. It is true that this has already been done on the Mersey Tunnel, but that line is more analogous to a city underground railway, and while the change is interesting and important, it has not the relative importance of that now made in the West of Lancashire. We recommend all who are interested in the economics of British railways to watch attentively the results of this progressive step on this portion of the Lancashire and Yorkshire Railway.

Metropolitan Highway Reform.

WHATEVER improvements may be made in the existing railway facilities of the metropolis, it is undoubtedly the fact that streets and roads will always remain the most important means of communication for the large bulk of the population, and those who have studied the question at all are aware that an immense amount of work remains to be done before the highways of London can be rendered entirely suitable for their intended purpose. No doubt a good deal might be accomplished by the removal of divers permanent obstructions, such as lamp posts, street refuges, and cab ranks, and also by the more stringent regulation of traffic. But more than this, viaducts for cross traffic and new main thoroughfares for general traffic

are required in the central districts, as well as various new thoroughfares, radiating from the centre to the outskirts, for the daily influx and efflux of persons and merchandise. Moreover, legislation is urgently required for the control of building operations in the outer suburban belt. New districts are now being built up round the metropolis without any thought as to the future, and there is no doubt that this practice will ultimately be the cause of serious trouble. New roads and streets that are being laid out in the suburbs are rarely designed suitably for taking any share of the through traffic, and merely act as feeders for the existing main roads, which become more and more congested every year.

The unfortunate thing is that we have at the present time nearly one hundred independent highway authorities in the metropolitan district, all taking a strictly local and narrow-minded view of their responsibilities, and all mutually jealous one of another. Much valuable evidence on the subject of traffic facilities has been taken by the Royal Commission on London Traffic, and there is a general consensus of opinion in favour of the establishment of one central authority, with full and absolute power to deal with all means of communication. This appears to us to be the only hope of salvation for the metropolis. The gradual improvement of streets and roads in the central districts and older suburbs could then be taken up systematically, and a carefully co-ordinated scheme could at the same time be prepared, so as to provide for the proper disposition of future highways in country districts that will sooner or later be merged in Suburban London. Now is the time for action, before property further increases in value, and before further mischief is done by incompetent or indifferent local authorities.

Local Obstruction to Tramway Enterprise.

It is very unfortunate that local authorities should so frequently prove themselves too exacting in their requirements from tramway companies, as this policy is clearly detrimental to the true interests of the community at large. We have on previous occasions called attention to the extortionate nature of such demands, a particularly glaring example of which is to be found in the action of various authorities in the western districts of the metropolis, and directed against the London United Electric Tramways. The company are now promoting a Bill with the object of securing powers for various extensions of their admirable system, and, owing to the extravagant demands made by the local authorities as the "price" of their assent, have felt compelled to abandon the whole of their proposals, with the exception of the extension from Hounslow to Staines. The abandoned lines are the following:—(1) The extension from Hounslow to Maidenhead; (2) the cross-town line to connect Ealing with Brentford and Richmond; and (3) the line over Kew Bridge. The expenditure proposed by the company on highway improvements in respect of 21½ miles of track, amounted to nearly £220,000, but the demands made by the local authorities would have involved an additional expenditure of no less than £642,630 on public works, quite apart from tramway construction.

Although the new line proposed to be constructed in Brentford was less than half a mile in length, the District Council declined to give their assent to the Bill unless the company guaranteed a total expenditure in public improvements of no less than £556,659. In the Slough district, the tramway company were quite prepared to carry out improvements at a cost of £32,000, but the authorities not only demanded an additional expenditure of £65,738, but insisted also that the conduit system should be adopted within the limits of their district. Moreover, it appears that the London County Council, availing themselves of a purely technical point, have managed to defeat the company's scheme for the construction of two lines of tubular railway at Hammersmith, intended to form underground railway connections with the existing surface tramway system. This link would have pro-

vided a service of electric cars running directly into the District Railway station, setting down and taking up passengers immediately alongside the station platforms, and would have been of immense convenience to the public.

It is perfectly reasonable that tramway companies should be compelled to contribute something towards the cost of public improvements. There is no justification, however, for the blackmailing tactics of some local councils, nor for the jealous obstruction offered by the London County Council with regard to facilities designed for the benefit of the travelling public.

A New Hypothesis on the Strength of Materials.

WHEN materials are tested merely for the purpose of ascertaining whether they are in accordance with a given specification, it is natural that the results should be of very limited value. For example, it may be specified that the ultimate tensile strength of steel for constructional work shall be not less than 28 tons per sq. in. nor greater than 32 tons per sq. in., with an elongation of 20 per cent. in 8 ins. The tests conducted for the purpose of determining whether the steel be in accordance with these requirements give no indication as to what might be expected from the material under different tests. In laboratory work, however, tests are applied with the object of completely determining the properties of the materials, and the results are carefully examined to see if any general laws may be obtained, or for the purpose of ascertaining what interrelation may exist between the various physical properties of the material. It may be inquired, for instance, whether it is possible to determine the shearing strength from the known tensile and compressive strength of a given material. The latter point of view is one taken up in a recently published paper, read before the Institution of Civil Engineers of Ireland. The author asks whether any definite relation can be established between the strengths of a material to tension, compression, and shear, respectively. He puts forward a hypothesis of the constitution of isotropic materials, the conclusions therefrom being compared witth experimental data chiefly obtained from laboratory tests. It would be impossible in a brief note such as this to follow the theoretical discussion of the question raised by the author, but we may point out that it leads to the following conclusions:—(1) That the compressive strength is greater than the shearing strength, and that both these strengths are greater than the tensile strength; (2) that the tangent of the angle of inclination on which shearing stress causes sliding is equal to the square root of the compressive strength divided by the tensile strength, and the value of that shearing stress is equal to the square root of the tensile strength multiplied by the compressive strength; and (3) that the strength of a material in pure shear is equal to or greater than its tensile strength.

The foregoing conclusions certainly appear to be supported by the records of various tests taken by the author from the Proceedings of the Institution of Civil Engineers. There are divergencies in one or two cases, but these are not of sufficient importance to invalidate the hypothesis put forward, which is certainly one of considerable interest to engineers. In spite of the attention which is paid in the present day to the testing of materials, there still remains a vast field for experimental work in the investigation of the properties of materials of construction, and in clearing up many apparently contradictory results that have been obtained in the past. The hypothesis to which we have directed attention is clearly deserving of consideration by those who are engaged in work of the kind, and within certain limits it may prove useful to engineers in estimating the strength of materials.

The Premium System in Government Dockyards.

THE following is a reproduction of a "NOTICE TO WORKMEN" received from the Secretary of the Admiralty and which is being placed in certain of the shops in H.M. Dockyards

On March 14th, 1904, the Premium System of Payment for labour will be introduced in this shop. At first it will be applied to certain classes of machine work, and if satisfactory results are obtained, the system may be extended.

The system will enable workmen to earn, in addition to their ordinary weekly wages, extra remuneration for doing work in less time than the fixed time allowed for it.

The system may be briefly described as follows:—

When a piece of work is given out, a certain time, based on known times taken for similar work done on ordinary time in this shop, will be allowed for it.

This time allowance will include all the necessary time for obtaining tools and materials, preparing the machine and lifting and setting the work in or on the machine, any removal and resetting, change of tools, and removing work after completion.

If the work is satisfactorily completed in less time than the fixed time allowed for it, the workman becomes entitled to a premium varying in amount with the time saved.

If on the other hand he takes longer than the time allowed, he will still be paid his ordinary wages.

From this it will be seen that while the workman may increase his wages by his own individual effort, he cannot lose money by the introduction of the system.

Premium will be calculated as follows:—

The value of a "premium hour" will be considered to be 1/48th of the workman's weekly wages, and the amount of premium earned on a job will bear approximately the same relation to the ordinary wages due for the time taken to complete it, as the time saved bears to the time allowed.

To give an example:—

Suppose a man is given 48 hours to do a job and does it in 36 hours, he saves 1/4th or 25 per cent. of the time allowed, and accordingly will be credited with 25 per cent. of the time taken to do the job, which is 9 premium hours, so that

A mechanic in receipt of 36s. per week, and whose "premium hour rate" would therefore be 9d., would receive 9 × 9d. = 6s. 9d. premium for this job in addition to his ordinary wages for the period worked.

Similarly:—

A skilled labourer in receipt of 24s. per week, and whose "premium hour rate" would therefore be 6d., would in the example quoted above receive 9 × 6d. = 4s. 6d. premium.

A convenient way for the workman to calculate his premium is to multiply the time taken by the time saved, and divide the product by the time allowed, all times being taken in hours. This will give the premium in hours which, multiplied by the "premium hour rate," will give the amount of premium earned.

Or it may be stated thus:—

$$\frac{\text{Time taken} \times \text{time saved}}{\text{Time allowed}} = \left\{\begin{array}{l}\text{Premium}\\ \text{time.}\end{array}\right.$$

Taking the case already given:—

$$\frac{36 \times 12}{48} = 9 \text{ Premium hours.}$$

The time taken will be recorded to the nearest quarter of an hour.

In calculating the premium the time taken will include all the working hours from the time of commencement of a job up to the time of commencing the next job.

Overtime, and night and day shifts, will be paid for at overtime rates as at present, but will only count as ordinary hours in the calculation of the "premium."

Lost time, or absence without leave, will count in the time taken Absence with leave will not be included in the time taken.

The working of the system will be as follows:—

Each workman on commencing a "premium" job will receive a "Job ticket," on which he will find a description of the work to be taken in hand, the date and time of commencement of the job, the time allowed for it, and other particulars as to ship or service, head of charge, &c

On this ticket the Shop Measurer will fill in the daily time worked, and particulars of overtime, leave, and lost time, and when the job is finished the time of completion will be inserted on it to the nearest quarter of an hour.

The ticket is then to be returned to the Inspector, and if the man's next job is also to be executed on "premium," the time of commencing the new job will be the same as that of finishing the previous job.

As soon as possible after a job has been inspected and passed as satisfactory, the amount of premium earned on it will be communicated to the workman.

Premiums will be paid weekly on the Friday following the week in which they have been earned.

It is to be clearly understood that a "premium" is not earned until the finished work has been inspected and passed as satisfactory.

If a man's work when finished does not pass inspection he will receive no premium for that job unless he can make good the work in the time allowed, in which case he will receive the premium on any saving of time still remaining.

No premium will be paid on articles that turn out defective, on account of faulty material or other causes, during machining or other operations; but if one or more of several similar articles, for which a covering time allowance for the whole is given, should turn out defective, the workman will still receive any premium earned on the rest of the articles, the premium being calculated on the saving of time made on the reduced time allowance corresponding in proportion to the number of articles satisfactorily finished.

No allowance will be made in the time taken for stoppages occasioned by breaking of straps, stopping of driving machinery, or any other cause.

In cases where a job is stopped in order to undertake more pressing work, or for any other purpose, the workman will return his "job ticket" to his Inspector, and the date and time of return will be noted on it (this being the commencing time of his next job if a "premium" job). The time spent on the job up to the time of interruption will be counted as part of the time taken, and on reissuing the ticket, the time allowance will, if necessary, be so revised as to give the workman as fair an opportunity of earning "premium" on the whole job as would have been possible had the work not been interrupted.

As far as practicable, time allowances for definite operations will not be reduced after they have been once satisfactorily established and regarded as standards, unless a new method of manufacture necessitating a revision of the time allowance be introduced. But if an established or standard time is seen to be operating unfairly to the workman, it may be increased with the sanction of the Principal Officer of the Department.

As some of the work in the Department may not be deemed suitable to be done on "Premium," it is to be understood that a man may be required to work on "premium" or on ordinary weekly time rate as occasion and the work may require.

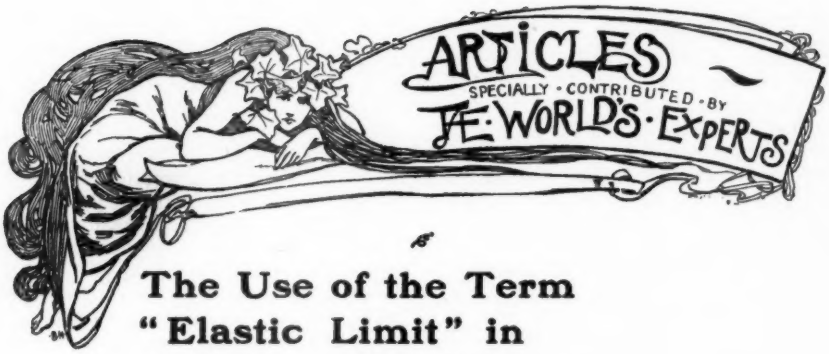
Apprentices will not for the present be employed on "premium" work.

It is hoped that the introduction of the Premium System will lead to the workmen taking an increased interest in their work, machines, tools, and equipment generally, and to keenness on their part in pointing out to their Officers where improvements may be made and time saved, resulting in better methods of work.

It is pointed out that increased energy and industry on the part of the workmen added to such improvements as may be adopted from their suggestions and resulting in work being done in less time than hitherto, will immediately benefit them by increasing their "premium" earnings.

By Command of their Lordships,

Evan Macgregor.



The Use of the Term "Elastic Limit" in Metals under Stress.

By W. C. POPPLEWELL, M.Sc., A.M.Inst.C.E.

FEW terms used by the constructive engineer are less perfectly understood and have been more often improperly made use of than that represented by the two words *elastic limit*. A careful examination of the true meaning of the term and of its limitations may not be without profit at the present time. During the last few years a great deal has been learnt about the elastic limit from facts revealed in the course of researches and investigations into the strength properties of materials, which are being constantly carried out by numerous scientific engineers in this country and abroad. This continually-increasing knowledge is obtained by means of appliances and instruments of precision, whose powers in the direction of accuracy are limited; and in this way a barrier is placed in the way of the seeker after further knowledge, which to a great extent limits the distance the searcher may travel towards his desired goal. But, while acknowledging the existence of these limitations and fully recognising the existence of further information in this direction which cannot be reached by our present means of investigation, it is possible to review the present state of our knowledge of the limits of elasticity in materials under stress. This is the purpose of the present article.

Elasticity in Metals.

For the purpose of this discussion the materials referred to will be the metals, for the simple reason that more is known about the properties of metals than of any other materials, and also because their elastic properties are of more importance to the engineer. For the present let us confine ourselves to simple direct stresses in tension or compression.

If a bar is subjected to a tension or compression load in a direction coincident with its geometrical axis, the effect of the load is to produce change of length, which, in the case of tension, means elongation, and, in the case of compression, shortening. It is recognised and well known that change of length always accompanies the imposition of stress, or, in other words, strain always results from stress. There is no such thing as absolute rigidity. The strains thus produced are of varying amounts and follow certain laws. Part of the strain may be only temporary, that is, may only remain so long as the stress is being imposed; and part of the deformation may be of a more or less permanent nature, and may constitute a change of form which remains after the removal of the load. Our usual conceptions of the meaning of elasticity depend on the temporary nature of the

strains, and upon the fact that they exist only so long as the stress remains.

Elastic Limit.

We are told that when a bar is loaded, and it is altered in length, and that if, when the load is taken off, the bar returns to its original dimensions, it is perfectly elastic. We are further told that as the loading is increased, there comes a point beyond which the change in length is partly temporary and partly permanent, and that the stress at which this begins to take place is the elastic limit of the material. This is the simplest, and in many ways the most scientific, description of the "elastic limit"; but as will be seen, there are great difficulties in the way of correctly determining this point, and its very existence depends upon the precision of the instruments used in its determination.

According to Hooke's law, the strain in a bar which is elastic is not only temporary, but it is also proportional to the imposed stress; and that for a given material it has a definite value for any given stress, defined by what is known as the Modulus of Elasticity.

Limit of Proportionality.

It is found from experiment that this proportionality between load and deformation, or stress and strain, does exist until a stress is reached beyond which the strains begin to increase for equal increments of stress. Take the case of a bar under tension in a testing machine: the loads are applied so much at a time, the increase being the same at every step. Means are taken for measuring the small extensions accompanying the tension stresses, and it is found that for every equal increase of load a correspondingly equal increase of length takes place. This goes on until a certain load is reached, beyond which the increments of stretch are no longer equal, but continually increase. This point has been given the name of "Limit of Proportionality," or "P-limit." This term clearly defines its own meaning, and could not be improved upon, but, unfortunately, it has in many cases been called the "Elastic Limit."

So far it is seen that there are two ways in which the "elastic limit" stress may be defined—viz. as the point beyond which permanent set is given to the bar, and otherwise as the stress beyond which the strain is no longer proportional to the stress. If these two points were found to coincide there would be no difficulty about the elastic limit; but, unfortunately, it is usually found that the first permanent set takes place at a stress below that at which proportionality appears to cease. It is therefore necessary to clearly distinguish between these two; they are often confused, and hastily assumed to be one and the same point. If the original term "Elastic Limit" is retained for the first—and that would seem to be the most reasonable course to adopt — then the second can still be called "P-limit."

It has been said that, using the most precise and accurate measuring instruments at present constructed, the elastic limit is found to lie below the proportionality limit; but the opinion is strongly held by some authorities—notably M. Fremont—that the elastic limit and the proportionality limit are coincident, and that it is only the want of accuracy and precision in our measuring instruments which makes it appear that they occupy distinctly different positions.

In his investigations into the position of the elastic limits of metals, M. Fremont has adopted the method of using a microscope to examine the polished surface of the metal under stress, and has taken as the elastic limit the point at which a slight dulling of the surface is shown by the microscope; and he maintains that there is only one true elastic limit, namely, the one which he has obtained in this way. In the course of his examination he found that this limit only appeared at first in one or more isolated spots, until the change gradually covered the whole of the surface; and in order to overcome the difficulty of noting the first appearance he used bars of gradually varying section, in which there was one small part where the stress was always greatest, and at which the appearance would change as soon as the stress at the smallest area reached the elastic limit stress.

As a result of these investigations of M. Fremont, a third and new definition of the elastic limit is created, which only tends to add to the already existing confusion as to what really fixes this point.

Besides these, there have at different times been other attempts to solve the difficulty. Of these, Styffe wanted to fix the limit as a point which was made to depend on the increase of permanent strain as depending on the rate of increase of stress. By this method a point is obtained for the limit which lies above the proportionality limit, and it is very difficult to obtain. In a similar manner Wertheim attempted to fix the limit as a stress where the permanent strain was a definite fraction of the original length of the specimen, namely $\frac{1}{30000}$. There are many objections to this plan, chiefly on account of the delicacy of the operation, and the great care required in carrying it out; and also because only part of this apparently permanent strain is really permanent—the remaining portion disappearing after the bar has rested for a time.

Yield Point.

The five points which have been mentioned as elastic limits are all more or less entitled to some claim on the term, but this does not apply to the point so often mentioned in commercial tests as the "elastic limit," but which is really the yield point. This is the stress, readily found, where the strain rapidly increases in amount as the load is slowly increased or is stationary, and is clearly discernible by means of compass measurements and by the appearance of the surface of the bar. The various ways of fixing this point include the dropping of the testing machine beam on to its bottom strop, advocated by Kennedy; the change in appearance of the surface of the bar, recommended by Styffe; the perceptible thickening of a line inscribed on the bar by a pair of compasses, which method is used by many experimenters in this country; and the employment of an autographic diagram, also much used, and recommended by Unwin. A way of finding the yield point, which the author has often employed, is to use an extensometer, and note the load at which the pointer or cross-hair begins to creep along the scale without any increase of load. This, though probably the most reliable method, is somewhat elaborate, and requires more time than can be spared in ordinary commercial testing operations.

Illustrations of the Three Limits.

Before going further, it will be well to inspect one or two diagrams which serve to illustrate what has been said regarding the several points which have been mentioned as "elastic limits."

The curves on Fig. 1 have been plotted from the results of a tension test on a turned bar of wrought iron, 1·62 in. diameter—the measurements of extension being taken with a Martens mirror extensometer capable of reading directly to ten-thousandths of an inch, and by estimation to one-hundred-thousandth of an inch. The extensions were measured on a 10-cm. length of the bar. It may be mentioned that, unlike most other extensometers, the Martens instrument does not measure the average extension on the two opposite sides of the bar at which connecting points have been attached; but enables the observer to measure these two extensions independently, and in this way to find out whether or not the load is being applied along the axis of the bar. This last is a most important feature of the Martens extensometer, as it makes it possible to apply it to the parts of actual structures in order to find out how stresses are being distributed in the part when under its load; in this connection the writer has made some very interesting determinations.

Referring again to the wrought iron bar in question, it was put into the testing machine, and loads applied by increments of two tons at a time. Before each new load was applied, the load was removed, and the readings on the extensometer scales, if any, taken. In this way it was possible to determine the point at which the reading did not return to zero after loading—the reading at zero load giving the permanent set produced by the last loading. By doing this, it was

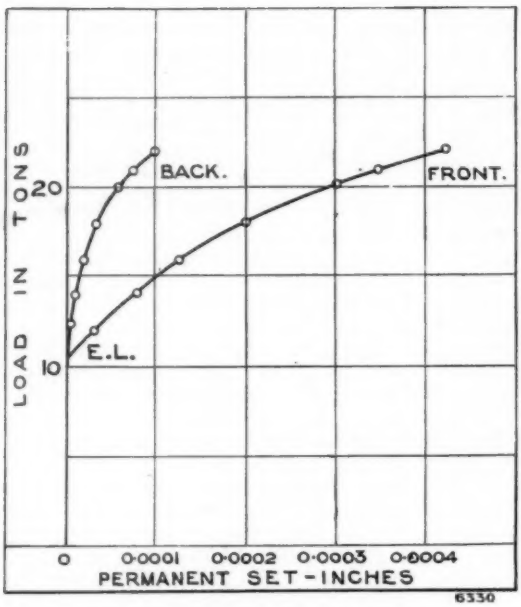


FIG. 1.—BAR OF WROUGHT IRON IN TENSION. DIAM., 1·62 IN. MEASURED LENGTH, 4 INS.

possible to determine, with a fair degree of accuracy, at what load the bar first began to take permanent set.

The curves on Fig. 1 represent the permanent set for each increment of two tons up to 22 tons load. Here loads are plotted vertically and extensions horizontally. It will be seen that until about 12 tons have been reached there is no permanent set, the reading line of the extensometer coming back to zero after each loading. At this load a permanent set is first noticed, and increases for each successive load. The two curves represent the readings on the two sides of the bar, one being marked on the diagram as 'back,' the other as 'front.' It will be seen that the permanent set, besides commencing at a definite point, increases by regular amounts, and also that this increase is more rapid on the front of the bar than on the back. From this it is gathered that the bar is not held uniformly in the grips, so that the line of pull lies between the axis of the bar and its front side, causing the stress on this side to be greater than at the back. The point where the lines first leave the vertical zero line, is marked on the diagram *EL*, being the load at which the elastic limit, as defined above, has been reached.

Now look at Fig. 2. This refers to the same test as the last. Two curves have been plotted, the upper one marked 'mean set,' and is an average of the two plotted on Fig. 1, again showing the elastic limit. On the other curve have been plotted the total average extensions. It will be seen that up to a certain load the points of the curve fall on a perfectly straight line, thus indicating true proportionality between load and extension, or between stress and strain. This point where the curve leaves the straight and begins to turn slightly towards the right is marked *PL*, indicating the "P-limit," or limit of proportionality. This point occurs at a load higher than the elastic limit just found.

This illustrates what has been previously said about the relative positions of the elastic limit and the proportionality limit, namely, that the latter is found to be higher than the former, but it is quite conceivable that, as M. Fremont considers likely, these two points really coincide, and would be found to coincide if the measurements of strains could be made with greater precision than is now the case. The way in which the proportionality limit is usually found, and this is probably the most reliable way, is to measure the strains corresponding to known stresses, and plot one against the other to a fairly large scale on true-squared paper. A straight-edge is then laid along the series of points so obtained. It will be found that the straight-edge can be made to coincide with the earlier part of the series of points, and it is clearly

seen where the line begins to leave the straight. It would seem that this point of departure ought to occur precisely at the same load as that at which it was first found that there was any permanent set; and that the more nearly would they so coincide the more precise were the strain measurements, and the larger and more accurate the plotting. As a matter of fact, it is found to be difficult, with specimens of the ordinary sizes, even when estimating to hundred-thousandths of an inch, to make the increments of strain quite uniform, though they are generally nearly so. It is also difficult to obtain perfect uniformity in the increments of load, and this leads to small unevennesses in the strains, apart from the intrinsic want of precision in their own readings. Taking all these considerations into account, the writer believes that the elastic limit ought to coincide with the proportionality limit. Whether greater precision in measuring would fix the elastic limit more accurately is open to doubt when the form of the permanent set curve is examined; the curve appears to run into the line of zero strains at a definite angle, and not to approach it as to a tangent.

Next, referring to Fig. 3, it will be found that a stress strain diagram has been plotted which shows the proportionality limit and the yield point for the same bar. In this case the extensions were taken with a Ewing extensometer on $1\frac{1}{4}$ in. of a tension specimen of high-carbon steel, $\frac{5}{8}$ of an inch diameter. The diagram forms a straight line up to the proportionality limit, which is shown at 4 tons, corresponding to 13·06 tons per sq. in. Beyond this point the line diverges from the straight, curves more and more rapidly towards the right, and eventually becomes horizontal, in this way showing a rapid increase of length without any increase in load. This is the yield point, and is marked at 6 tons or 19·74 tons per sq. in. on the diagram. It may be added that the maximum strength of this specimen was found to be about 47 tons per sq. in. To anyone who is observing the extensometer

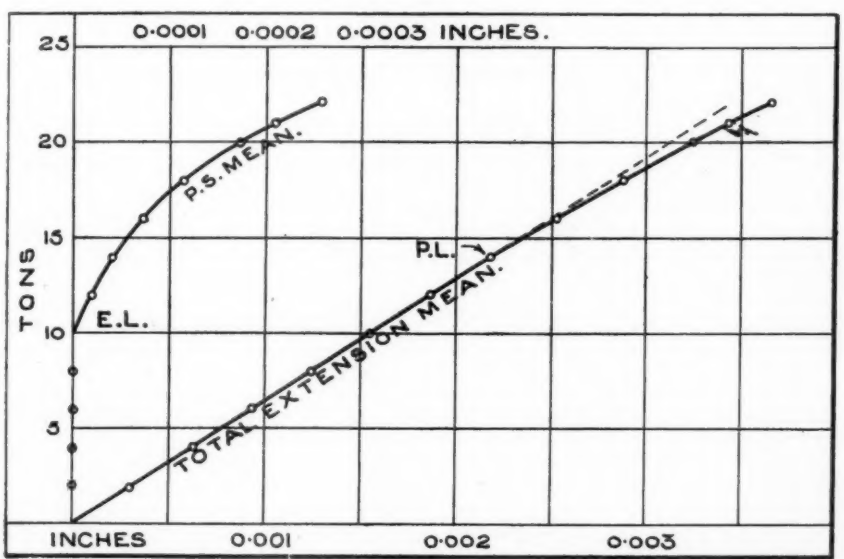


FIG. 2.—SAME BAR AS FIG. 1.

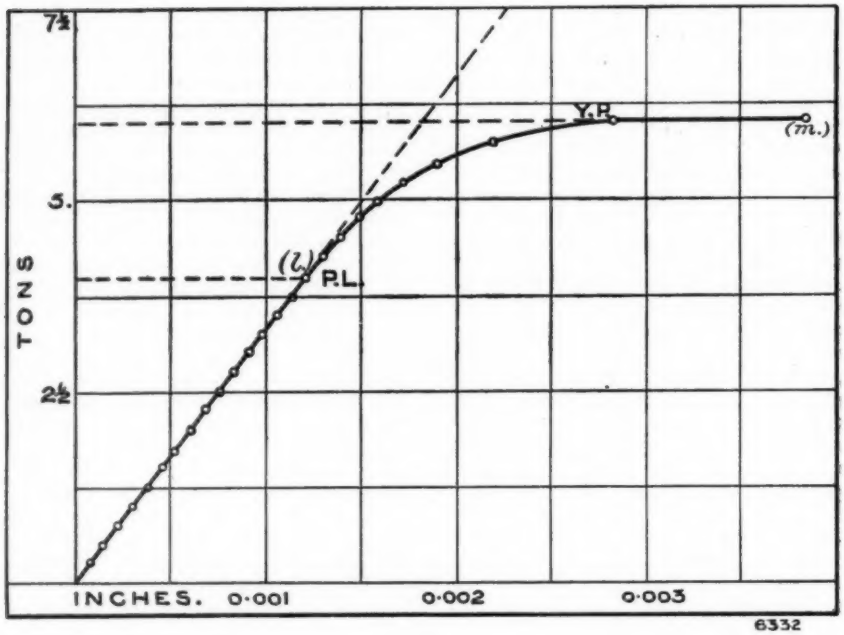


FIG. 3.

readings this yield point is determined with great certainty by noting when the reading line begins to creep along the scale without any increase in the load. It is not necessary to take a series of observations, but simply to watch the scale as the load is being gradually increased, and it is at once seen when the creeping begins. For commercial purposes the use of an extensometer is generally found to occupy too much time, and the yield point is more usually found by using a pair of dividers or watching the drop of the beam, though the latter is apt to be misleading in some cases. Another plan which has been mentioned is to let the bar tell its own tale by drawing an autographic diagram. Three such diagrams are shown on Fig. 4, the yield point being indicated in each case. In the curve (*a*) taken from a mild-steel bar, the position of the point is unmistakable, and is shown by the distinct horizontal jump in the curve, when yielding takes place. It is to be noticed that the early part of this step is similar to the curved part of the diagram on Fig. 3, but drawn to a much smaller horizontal scale; the portion referred to is lettered *l m* in both diagrams.

The second of these curves (*b*) has a much less distinctly marked yield point, and the third one (*c*), for a bar of wrought iron, is even worse. In cases like the last, the autographic diagram is apt to fail as a means of locating the yield point, unless great care is used in manipulating the apparatus, and it is in the hands of a very experienced observer. In any case, the actual quantitative value of the yield-point load should not be scaled from the diagram, but read off on the scale of the machine as soon as it is seen that the pencil is leaving the elastic line.

The writer has tried having three observers watching for the yield point on the same test. One used an extensometer, the

second tried the measured length of the bar with a pair of dividers, while the third watched for the drop of the beam. It was found that the extensometer man noted the point first, the dropping of the beam came second, and the dividers was last.

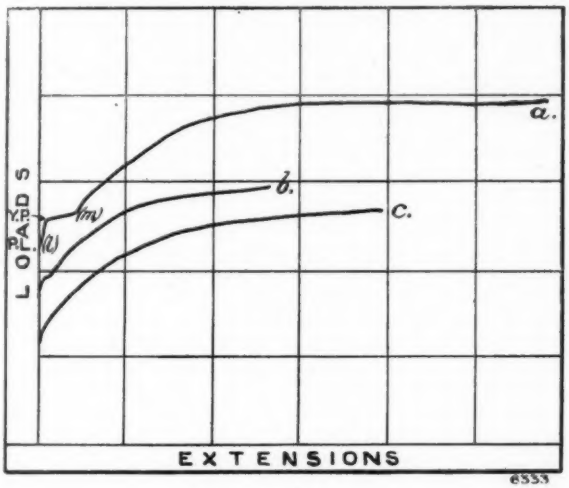


FIG. 4.

Unsymmetrical Loading.

It has already been pointed out that in very many cases the bar under test is loaded unsymmetrically, with the result that there is a greater stress on one side than on the other. The curves of extension for the two sides of such an unequally loaded bar are shown in Fig. 5; this refers to a cast-steel round bar rather more than 2 sq. ins. area. It will be seen that the two limits are not very far apart, that on the right hand diagram occurring slightly earlier than in the case of the other. As the extensions—and consequently the stresses—of the right hand side are greater than those for the left, as shown by the greater slope of the curve, the proportionality limit will occur first here. The effect of this slight yielding appears to throw the load nearer the other side, and bring the stress to a more nearly uniform condition; so that the proportionality limit is reached on the left side almost as soon as on the right. This approach to uniformity is shown on the diagram by the fact that the two dotted lines are nearly parallel. This would appear to show that where the loading is slightly eccentric, the general proportionality limit will only be very little in excess of the same point for the more greatly stressed portion of the bar.

The above are only isolated examples

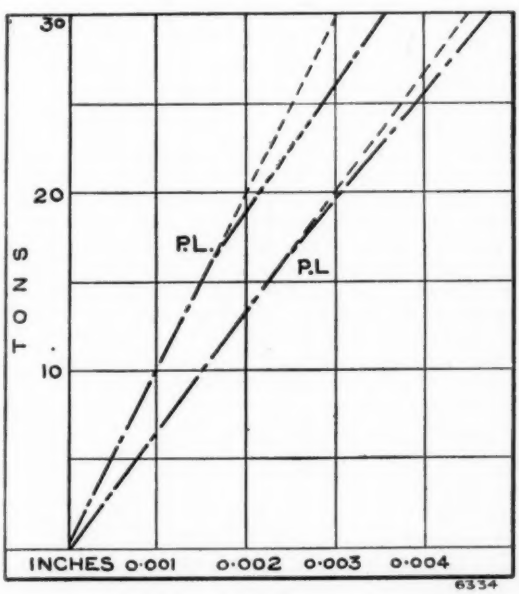


FIG. 5.

taken from a very large number of similar experiments made in the Testing Laboratory of the Municipal School of Technology, Manchester, and are only meant to serve as illustrations of some of the points discussed.

Changes of Limit by Previous Loading.

In what has been said so far, it has been assumed that the limit, whether elastic limit, proportionality limit, or yield point, is a fixed point for a given material. But this is only so long as the material is always in precisely the same condition.

It is well known that if the proportionality limit has been found for a bar under a tension load, and the load is raised to a point somewhat in excess of the limit just determined, then on reloading the bar with the intention of finding the limit a second time, this will be found to be now at a higher stress, not far from the maximum stress applied in the first loading. In other words the limit will have been raised by this previous loading, and not only so, but it may be raised time after time by successive loadings. Moreover, these artificially raised limits can be made to again fall to somewhere near the original point in several ways, such as resting for a time, by the application of heat, or by hammering. If, however, the bar has been previously loaded beyond the limit in tension, then the loading is reversed and the stress is carried beyond the limit in compression, it will be found that on now reloading in tension, the limit, instead of having been raised by the previous loading, will have been depressed. So we are led to conclude that the effect of previous loading beyond the limit will be to raise the limit for loading in the same direction, and to depress it lower when loading with the same stress in the opposite direction, all these being artificially produced limits. Further, it is found that while an artificially raised limit is lowered by a reversed loading, an artificially depressed limit will be raised by a reverse loading. The result is that after a series of reversed loadings, carried in each case just beyond the limit, the limit settles down to a fixed value which is the same for compression as for tension; this point has been styled the natural limit for the material. The limit found on the first loading of the bar is generally higher than the natural limit, and has probably been artificially formed in the process of manufacture or by after treatment. It has been found that bars return to their primitive limit after resting for a few weeks or months, or more quickly by the application of a temperature such as that of boiling water.

Summary.

The subject of these remarks has a very important bearing upon the results of commercial tests of materials, especially of iron and steel, and now that there is an effort being made to introduce standard methods into the testing of materials in this country, it would seem reasonable to suppose that this question of elastic limits should be put on a much more definite basis than now exists.

Looking back at what has just been said, it will be seen that there are really two fairly well-defined limits found during the loading of a bar of iron or steel in tension. These may be called the limit of proportionality (or "P-limit") and the yield point. The former of these is less easy to determine than the second, and its exact location partly depends on the precision of the measuring instruments used in its determination, and in all probability it coincides with the true elastic limit. In most commercial tests it is only the yield point that is required, and this is the point which is generally found and erroneously given as the elastic limit. It may safely be said that whenever the elastic limit is spoken of in connection with a commercial test what is really meant is the yield point. Of course, if it is generally agreed to call this point the elastic limit, well and good; but this should be clearly stated, and the existing ambiguity removed once for all. The objections to this use of the term will be gathered from what has been said above; and, in addition, it may be stated that many of the high-carbon steels show no yield point, and a limit can only be determined by using instruments of precision.

Besides defining what is meant by the limit given in commercial tests, it would be well if the manner of finding it could be clearly defined, and one standard method adopted. This would lead to uniformity, and enable useful comparisons to be made.

And, lastly, where the limit given is to be in any sense used as a criterion of the quality of the metal, not only should the nature of the limit and its manner of determination be clearly understood, but the history of the test specimen as regards its treatment between leaving the rolls and the operation of testing should be known.

Modern Woodworking Machinery.

By M. POWIS BALE, M.Inst.C.E., M.I.Mech.E.

(Continued from page 230.)

Section II.—Planing and Moulding Machines.

After the log has been converted by the sawing machines, it passes on to the various planing and moulding machines, to be worked into floor boards, mouldings, joinery and cabinet work, etc.

Planing and moulding machines may be roughly divided into three classes:—(1) centre-feed machines (four-cutter), (2) overhanging spindle machines (four-cutter), and (3) vertical spindle machines; but there are numerous modifications of these to suit special work. The first two classes usually carry four or more sets of cutters, and the third class one or two sets.

For heavy high-class work the centre-feed machines are to be preferred, but for light moulding, etc., the overhanging spindles are very useful. The third class are especially adapted for curved moulding, shaping, recessing, etc.

As in other woodworking machines, the "box" or solid framing is to be preferred for planing and moulding machines, as it offers a better resistance to the high speed and various stresses set up than sectional framing.

Box-framing is higher in first cost, but this is more than counterbalanced by its increased strength and resistance to stress, by economy of material in ratio to strength and by its greater neatness in design.

The cutter spindles should be of steel and supported by bearings of ample area, more especially where they are subject to considerable belt-tension. As regards the material for bearings, English practice is still in favour of gun-metal or phosphor-bronze in preference to white metal, as usually employed in America. Some difference of opinion exists amongst makers as to the best position in the machine in which to place the vertical or side-cutter spindles in centre-feed machines which operate on the four sides of the wood at once. Some fit them at the end of the machine to act on the wood after it has passed the top and bottom cutters, others put them in the centre of the machine, between these cutters. The plan of placing the cutters at the end of the machine renders them rather more accurate for adjustment; but the writer is in favour of placing them in the centre of the machine, as the wood is then directly under the action of the holding-down apparatus, and there is less liability of its jarring when under the operation of the cutters. In either case, however, it is important that a pressure apparatus be fitted close up to all of the blocks, and rollers are to be preferred to pads. Again, many American makers arrange the top cutter-block to operate on the wood first instead of the bottom one; which is undoubtedly wrong, as the bottom one provides a true surface for the board to rest on whilst under the action of the other cutters.

To secure a constant and even feed and prevent the wood slipping, it is important that all the feed rollers be expansively geared up together, and that the rollers be of ample diameter. The gearing is best machine-cut, and intermediate pinions should be made of steel or phosphor-bronze. The speed of feed should be variable, from say 10 to 150 ft. per minute. For producing under-cut hand-railings, mouldings, etc., the side-cutter spindles should be arranged to angle, and duplicate blocks fitted for tongueing, grooving, beading, etc. Shimer or similar heads can be recommended, as they have

a side clearance which permits of very rapid work. Makers now usually mount the bottom cutter-block in a drawer, which can be withdrawn for sharpening the irons, and in one case a positive lateral motion is given to the block so as to give a clean cut, and it is claimed for this arrangement that better work is thus produced. It is of vital importance that all cutter-blocks and spindles be true and in absolute balance, and where movable blocks are used they must be bored truly parallel or they will spring in use. They should in all cases be planed or turned after being fitted to the spindles. The countershaft is best separate from the machine, as longer driving-centres can be thus obtained, and the vibration of the machine is lessened.

Where very fast speeds are attempted, it need hardly be said increased care in the design and manufacture of the various details of the machine is necessary. The main frame should be extra massive and quite rigid, the feed-gear be machine cut and pressure apparatus absolutely positive, the bearings of increased area, the cutter-block spindles strong and quite free from seams and be carefully ground into their seats. Especial means for securing a constant lubrication of the bearings must be taken, and the driving-belt area should be increased to avoid any chance of slip. The driving-belt centres, too, should be of ample length, the various cutters be machine ground to the correct angle and be kept in perfect condition.

Speed of Planing and Moulding Machine Cutters.

In well-constructed and equipped machines, a speed of 5,000 ft. to 8,000 ft. per minute at the cutting edges of the irons may be taken as a standard.

Fig. 16 illustrates a high-speed roller-feed planing machine for

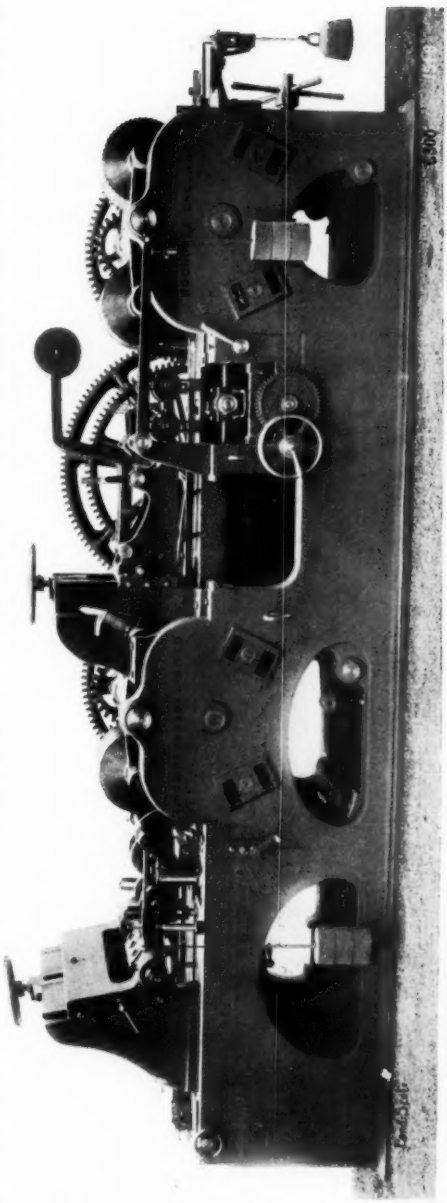


FIG. 16.—HIGH-SPEED ROLLER-FEED PLANING MACHINE BY MESSRS. THOS. ROBINSON AND SON.

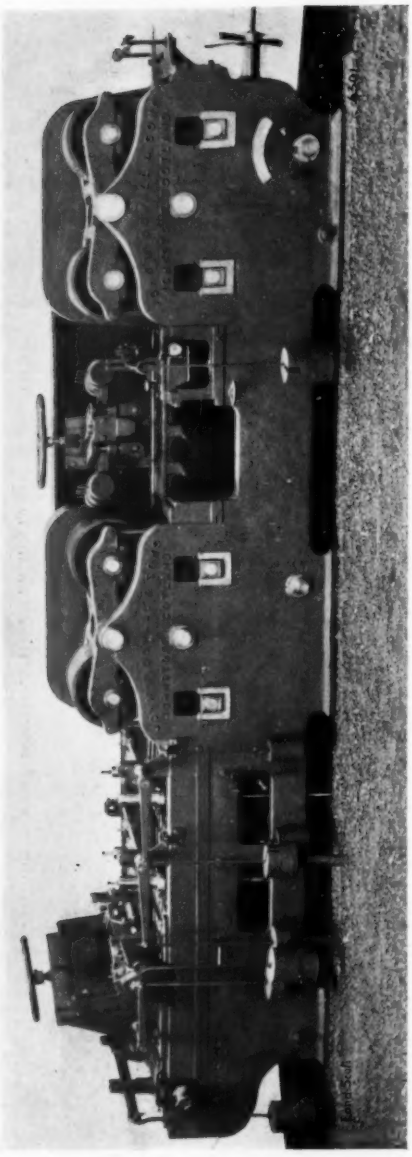


FIG. 17.—ROLLER-FEED PLANING MACHINE BY MESSRS. JNO. MCDOWALL AND SONS.

flooring and match-boarding by Messrs. Thomas Robinson & Son, Ltd., Rochdale.

The main frame is of very massive construction, to overcome the vibration arising from the high working-speeds. To avoid heating, the cutter-block spindles are mounted in patent self-lubricating bearings, so arranged that a constant supply of oil automatically circulates through the bearings as long as the spindles revolve.

The feed consists of eight rollers of large diameter, all geared together and driven by powerful spur-gearing. The top series of rollers can be raised or lowered simultaneously, and the lower rollers are adjustable vertically to allow for wear. When fully complete this machine is fitted with five sets of revolving cutters, with additional fixed smoothing cutters to each set. The first or bottom revolving cutter-block can be drawn out of the machine for sharpening or adjusted vertically to suit the depth of cut. The side-cutter spindles are fitted with Shimer heads. All cutters are fitted with roller pressure apparatus, each set being regulated by separate weighted levers so as to suit the varying width or thickness of the boards. The levers over the fixed irons can be raised simultaneously for the removal of the drawer.

Fig. 17 illustrates a roller-feed planing machine for planing, thicknessing, tonguing, grooving, and plain-jointing timber by Messrs. John McDowall & Sons, Johnstone.

The feed consists of four pairs of feed-rollers, all geared together by machine-cut toothed gear. The top rollers can be adjusted simultaneously to suit the thickness of timber, and the bottom rollers are adjustable for wear. The first revolving cutter-block and fixed irons, which operate on the under surface of the wood, are mounted in movable drawers, and the front filling-in plate to the revolving block can be raised or lowered to allow of variation in the thickness of cut.

Eight counter-weighted pressure-rollers are mounted over the fixed

irons; these are trained to the same angle as the plane irons, and can be adjusted independently or simultaneously as may be required.

It is claimed as a feature in this machine, that four side-cutter spindles are introduced instead of the usual two, more particularly for tonguing and grooving flooring, the first two spindles being employed to rough out and the last two for finishing. The top cutter is adjustable vertically, and is arranged to give a shearing cut, and a beading cutter-block is mounted at the back end of the machine. The cutter spindles, which make some 5,500 revolutions per minute, are mounted in self-oiling bearings.

The feed is variable by means of cones up to 150 ft. per minute.

Fig. 18 illustrates a high-speed planing and match-boarding machine by Messrs. A. Ransome & Co., Ltd., Newark-on-Trent.

This machine has been designed for preparing flooring at a high rate of speed, and includes planing, tonguing, grooving, edging, thicknessing, and beading at one operation. The feed consists of four pairs of rollers of large diameter, all of which are driven by gearing placed outside the frame of the machine. The top rollers can be raised or lowered simultaneously by a screw placed at the end of the machine. The pressure apparatus consists of a series of rollers and counter-weighted levers, and is fitted to all cutters. The first bottom revolving cutter is mounted in a movable drawer, as are also the fixed smoothing irons which follow it. The side cutters are Ettinger's patent expansion blocks; these are adjustable separately, both transversely and vertically, and are not placed opposite each other. The top cutter-block is arranged to rise and fall, and a supplementary cutter for beading is fitted at the end of the machine, and fixed smoothing-cutters to the side-cutter spindles. Speed of feed variable up to 150 ft. per minute.

Fig. 19 shows a patent double-planing and matching machine from the designs of Messrs. John Pickles & Son, Hebden Bridge. In this machine two boards are planed on all four sides at once. The

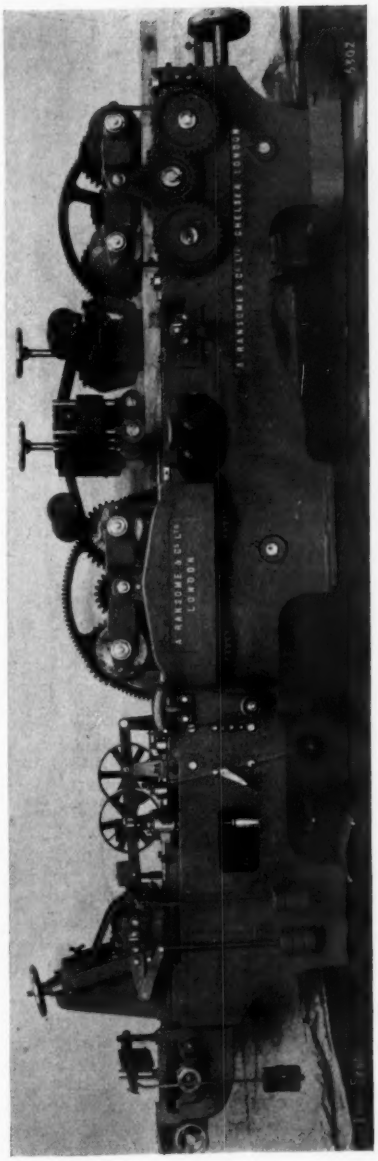


FIG. 18.—HIGH-SPEED PLANING AND MATCH-BOARDING MACHINE BY MESSRS. A. RANSOME AND CO.

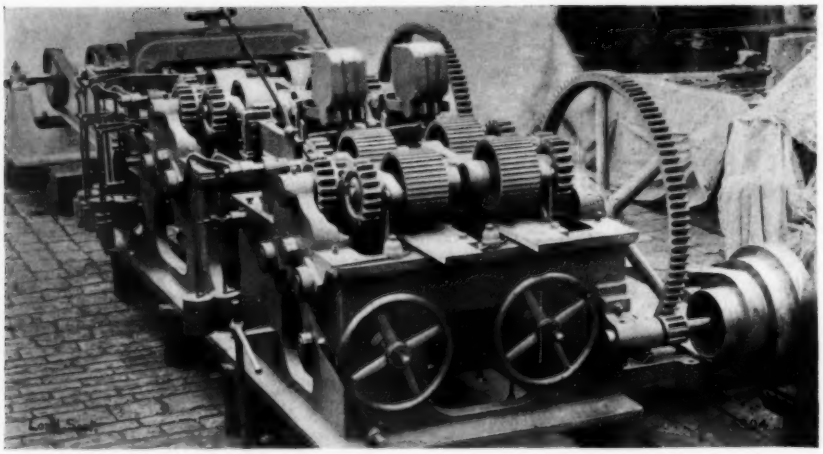


FIG. 19.—PATENT DOUBLE-PLANING MACHINE BY MESSRS. JOHN PICKLES AND SON.

boards are fed through the machine by eight adjustable feed-rollers, and are first of all acted on by one bottom revolving cutter, and then by stationary irons fitted with an independent lever-pressure arrangement. The edges of the boards are then tongued and grooved by two pairs of side-cutter spindles carrying Richardson's patent cutter-heads, and the tops of the boards are finished by an adjustable top cutter-block. All necessary down- and side-pressure apparatus, to keep the wood steady under the action of the cutters, are fitted and are regulated by means of counter-weighted levers. The top and bottom cutters are arranged to give a shearing cut. The speed of the feed motion is regulated by cone pulleys, and it is arranged with a maximum speed of 120 ft. per min. If an extra finish is required, additional fixed irons can be fitted to act on every side of the boards.

Fig. 20 shows a central roller-feed planing machine (Westman's Patent). The feed of this machine consists of four pairs of geared rollers of large diameter driven by two sets of worm-gear, by which arrangement it is claimed that an absolute and steady feed is obtained without any increase in the power used. A six-speed cone pulley is fitted on the worm-gear shaft, giving a readily variable rate of feed ranging from 70 ft. to 160 ft. per minute.

Five sets of revolving cutters are fitted, with additional fixed smoothing cutters for all four sides of the wood. The bottom fixed cutter is duplicated in separate drawers, and a fresh one is always ready to be brought into use without stopping the machine. The pressure above the cutter is regulated by means of a handle on the front of the machine, and is connected with the cutters in such a way that, when the pressure is applied, the cutter is raised above the surface of the table, and *vice versâ*. The pressure-wheels above the cutter work parallel with the edges of the knives, which are placed at a very acute angle. The fixed side cutters are adjustable to different widths from the working side, and also to and from the side-cutter spindles. The pressure between the side-cutter blocks—which are fitted with chip breakers—is regulated by means of adjustable rollers. A top fixed cutter is mounted behind the top revolving cutter, and lastly an adjustable beading cutter at the end of the machine.

Fig. 21 shows a high-speed planing and

moulding machine by Messrs. Thos. Robinson & Son, Limited, Rochdale.

This machine has been specially designed for the production of mouldings at the highest rate of speed. It is fitted with four revolving cutter-blocks running in bearings of phosphor-bronze. For the production of wide mouldings, spouting, etc., the top cutter-block, in addition to a vertical adjustment, is usually also arranged to cant so as to equalise the overhang of the cutter. The feed consists of four rollers, all of which are driven. The two top rollers are mounted on swings which can be readily raised or lowered, and the bottom roller bearings are fitted in slots, allowing them to be adjusted vertically. Adjustable pressure apparatus is fitted to all cutter-blocks.

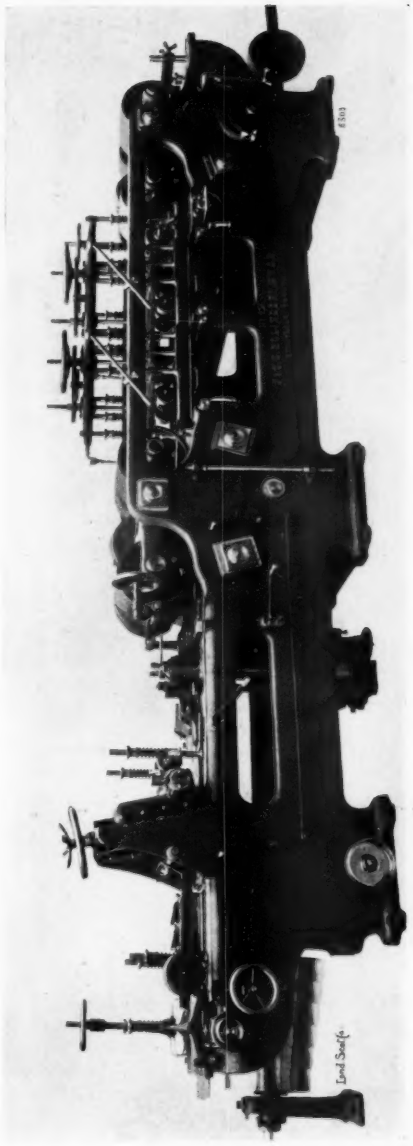


FIG. 20.—CENTRAL ROLLER-FEED PLANING MACHINE (WESTMAN'S PATENT).

Vertical Spindle Moulding Machines.

For moulding and shaping all kinds of curved and irregular work these are most valuable machines, and are largely used; they will also stick straight mouldings, tongue, groove, edge, and perform many other cognate operations. The main frame should, preferably, be cast in one piece. The spindle should be of steel, and in the best practice the long driving-pulley is forged solid with it, the spindle arranged to rise and fall, and the head slotted to carry fine cutters; it should also be adapted for carrying either small spindles, a square block, or solid wing-cutters, to suit different classes of work. The bearings should be long, and by preference made of phosphor-bronze, and be adjustable vertically. In single-spindle machines the best plan for reversing the motion of the spindle is by means of a countershaft carrying two sets of fast and loose pulleys, which are made to run in both directions by means of open and crossed belts. The countershaft should not be attached to the frame of the machine.

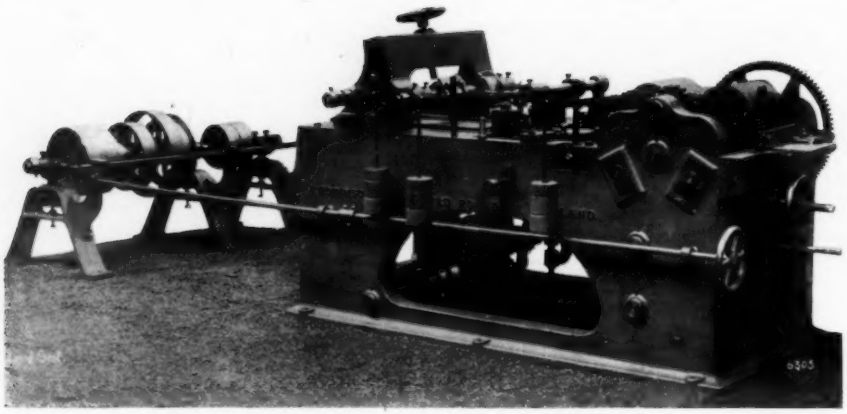


FIG. 21.—HIGH-SPEED PLANING AND MOULDING MACHINE BY MESSRS. THOS. ROBINSON AND SON, LTD.

Where much recessed moulding, tracery work, etc., is required, an overhanging-spindle machine is used, either by itself or in conjunction with an ordinary vertical spindle. Speed, 4,000 revolutions per minute.

Fig. 22 shows a vertical spindle-moulding machine by Messrs. John Sutcliffe & Son, Ltd., Halifax. This machine is adapted for working curved and irregular shaped moulding, cutting raised panels, etc. The cutter-spindle runs in long bearings of phosphor-bronze and is arranged to rise and fall, it is fitted with a loose top-spindle which has grooved washers for holding the cutters by compression, or will carry a square cutter-block or solid reversible cutters. The top spindle can be removed, if necessary, and replaced by a slotted spindle for carrying flat cutters. The fence is made in halves, each of which is mounted in adjustable slides and fitted with sliding front-plates by which the opening between the fences can be readily regulated. The table is fitted with loose ring-plates, and dovetail grooves and bolts for holding the fence and springs. The countershaft is arranged to drive with open or crossed belts.

A dovetailing apparatus for cutting dovetails in drawer and box slides, etc., can be readily fitted to these machines.

Miscellaneous Planing and Moulding Machines.

A large variety of planing and moulding machines have been introduced to suit special manufactures, such as hand-feed surface-planing machines, panel-planing and thicknessing machines, thin-stuff planing machines, travelling-table trying-up machines, etc. Although hand-feed surface planers are comparatively new machines, large numbers are now in use, and are extremely useful for short work, taking wood out of "wind," making glue joints, beveling, squaring up, rebating, mitring, panel raising, wave moulding, angle gaining, etc. The main frame is usually cast in one piece, and the tables should be arranged to rise and fall in an angle slide to avoid coming in contact with the cutters.

Panel-planing machines are also largely used, and have proved themselves very valuable to builders, cabinet makers, coach builders, pattern makers, etc. They are fitted with a roller-feed, driven by toothed or chain gearing. We can speak well of the latter arrangement, as, owing to the constant downward pressure of the chain, different thicknesses of wood are allowed to pass without affecting the tension of the feed-rollers.

In machines for planing wide panels it is important that the cutter-spindle be of sufficient diameter to avoid any chance of springing when taking a heavy cut. The irons should be arranged to give a shearing cut, and the sides of the cutter-block shaped to form back-irons up to the cutter. For wide and difficult work spiral irons are sometimes used, and these, although slow, turn out very fine work, but require a special grinding apparatus to keep them in order. Where jointing, tonguing, grooving, etc., is required, side cutters can be fitted to these machines with advantage. Speed of variable feed-gear, say from 10 to 50 ft. per minute.

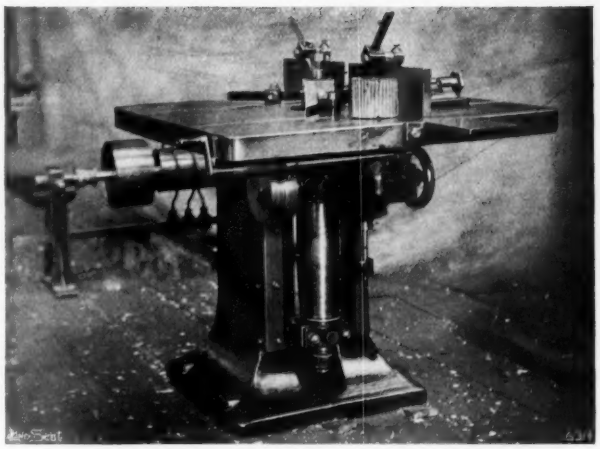


FIG. 22.—VERTICAL SPINDLE MOULDING MACHINE BY MESSRS. JOHN SUTCLIFFE AND SON, LTD.

Although travelling-table trying-up machines have, for light work, been somewhat superseded by hand-feed surface planers, they are valuable machines for taking timber out of "wind," heavy trenching, etc. Pressure rollers should be fitted at both front and back of the cutter-block, and vertical side-cutters can be fitted to these machines, if desired, for edging, etc.

For planing thin stuff on one side only, a machine with a fixed cutter is employed, the wood being fed over it by means of a large feed-roller, usually covered with india-rubber, the feed being usually speeded to propel the wood through the machine up to some 700 ft. per minute.

Fig. 23 represents a machine by Messrs. J. Sagar & Co., of Halifax, in which the operations of hand-feed surface-planing and roller-feed panel-planing and thick-

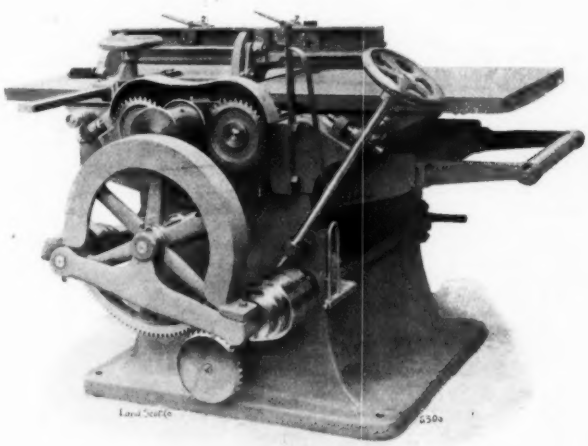


FIG. 23.—COMBINED SURFACE, PANEL-PLANING AND THICKNESSING MACHINE.

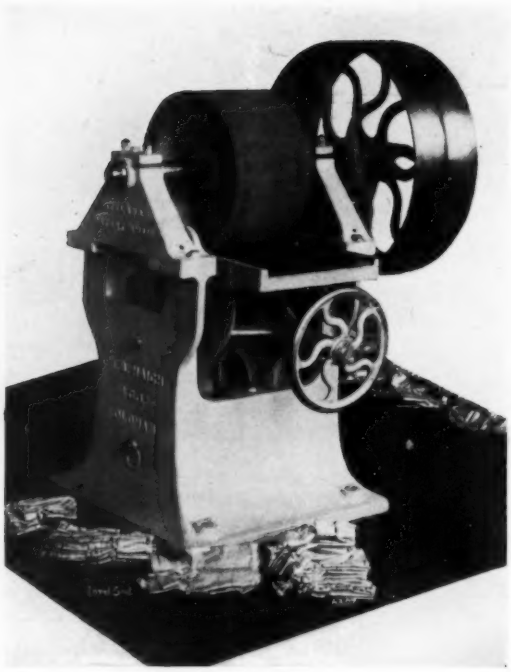


FIG. 24.—THIN STUFF PLANING MACHINE BY MESSRS. W. R. HAIGH AND CO., LTD.

nessing are combined. For surface-planing and taking out of "wind," the wood is passed along the upper table and over the revolving cutter by hand, and for planing and thicknessing it is placed on the lower table, and fed beneath the cutter by means of geared rollers. The frame of the machine is self-contained, and the cutter block and spindle are of steel, and forged in one piece. The spindle revolves in extra long bearings of phosphor-bronze, and the cutters are arranged so as to give a shearing cut. Flexible pressure-bars are fitted on both sides of the cutter-block. The feed-gear is speeded from from 9 ft. to 40 ft. per minute, and can be stopped without stopping the cutter-block. The gear wheels for driving the feed are cut from the solid, and placed wholly on one side of the machine. Four steel feed-rollers are fitted—two being placed before the cutter-block and two behind. An adjustable fence, worked by a lever-canting arrangement, is fitted. These machines are made to work wood up to 30 ins. by $7\frac{1}{2}$ ins.

Fig. 24 shows a thin-stuff planing machine by Messrs. W. R. Haigh & Co., Ltd., Oldham. This machine is adapted for planing lap-boards, cigar-box, and similar light woods, on one side only, at a high rate of speed. The planing is done by means of a stationary cutter mounted in a cutter-box fitted in the table carrying the wood. The wood is fed over the cutter by an indiarubber-covered wheel, which makes some 250 revolutions per minute. The table is adjustable by means of a hand-wheel and screw to suit varying thicknesses of wood, which can be planed as fast as it can be placed in position. The main frame of the machine has an extended base, and is cast in one piece.

(To be concluded.)

Carburettors, Vaporisers, etc., used in Petrol Engines.

By E. BUTLER, M.I.Mech.E., A.I.E.E.

(Continued from p. 118.)

The Second Distillate from Petroleum.

OWING to the pungent and comparatively viscid nature of the natural crude oils, perfect combustion in engines of small size is with difficulty obtainable, and in consequence of this the exhaust products are decidedly objectionable. Hence these crude oils are entirely unsuitable for many purposes. With small industrial engines the second petroleum distillate is generally used, familiarly known in the trade as kerosene oil. This is the well-known illuminating oil, sold universally under such well-known titles as Daylight, Sunlight, Tea Rose, White Rose, Rock Crystal, Russolene, etc., etc., and always understood by the name of paraffin lamp oil.

This product is a pale blue or straw-coloured pungent liquid of about $\frac{8}{10}$ths the weight of water, and does not give off an inflammable vapour unless heated to a temperature higher than 100 degs. Fahr. (The legal test regulation varies slightly in different countries.) Special distillates, however, known as Lighthouse and Trinity-house oils, have a much higher flashing point, and are used in lighthouses for the signal lamps and siren oil-engines. In these oils all the more volatile elements are more completely distilled out, leaving a product of nearly even composition.

Engines using Kerosene or the heavy Oils.

For internal combustion engines to successfully work with any of the kerosene oils, they must be provided with some form of volatiliser, vaporiser, gasifier, or its equivalent. The various systems in use may be generally divided into two series: firstly, those which are adapted to the ordinary form of gas-engine cylinder and do not require any special cylinder explosion chamber; and, secondly, those requiring a special explosion or breech-chamber for each cylinder of the engine.

The first series may be subdivided into three classes, viz. :—

Class 6.—Engines having a separate exhaust-heated volatiliser.

Class 7.—Engines having a separate flame-heated vaporiser.

Class 8.—Engines having a separate exhaust-heated carburettor.

The second series may be subdivided into two classes :—

Class 9.—Engines having a combined vaporiser and explosion chamber forming part of the cylinder head.

Class 10.—Engines having a vaporiser forming part of the cylinder head, either surrounded by a volatilising chamber, or depending on an external flame.

Class 11.—Engines having no special breech-chamber or vaporiser and depending entirely on high compression.

Engines using Exhaust-heated Volatilisers.

Class 6.—The Priestman, Griffin & Halliday engines are provided with exhaust-heated volatilising chambers, into which is sprayed a mist of oil spray and air by a compressed air jet, worked by an auxiliary air-pump (*vide* Figs. 15, 16, 17). The Butler, Rocket, Barker and Longuemare, etc. engines obtain the same result without the air-pump by utilising the inspirative action of the motor piston to draw an atomised spray of oil and air into an exhaust-heated volatilising chamber. The Butler system, in particular, is adapted for engines of very large size, as it is entirely independent of external heating either at starting or afterwards. Engines fitted with electric ignition are capable of

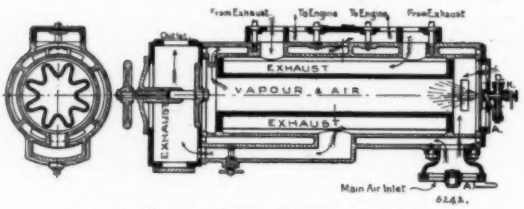


FIG. 15.—"GRIFFIN" EXHAUST-HEATED VOLATILISER.

D and *K* Compressed-Air and Kerosene to Spraying Nozzle.
A Air Inlets with Regulators.

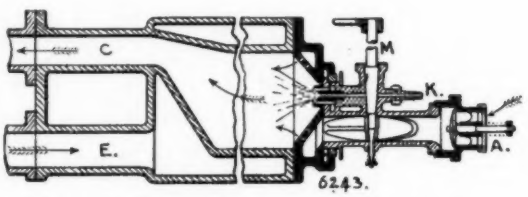


FIG. 16.—"FRIESTMAN" EXHAUST-HEATED VOLATILISER.

A Air Inlet. *C* To Cylinder.
K Kerosene Inlet. *E* Exhaust from Cylinder.
M Regulator to Governor.

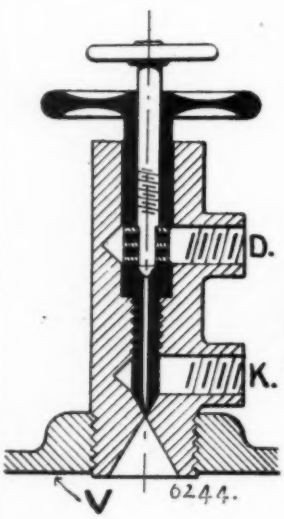


FIG. 17.—"CLARKSON-HALLIDAY" ATOMISER NOZZLE.

D Compressed Air.
K Kerosene Supply.
V Volatilising Chamber.

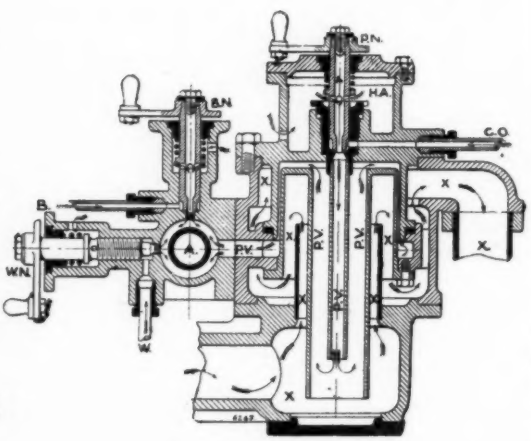


FIG. 18.—BUTLER'S VOLATILISER.

A Air Nozzle of Inspirator.
B Benzine Supply for Starting.
BN ,, ,, Feed.
CO Crude Oil Supply.
HA Hot Air.
PN Crude Oil Supply Feed.
PV Oil Vapour and Air.
X Exhaust Gases.
W Water Spray.
WN ,, ,, Regulator.

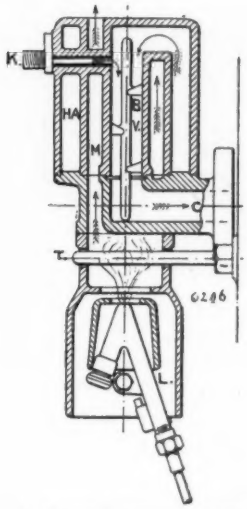


FIG. 19.—"SMITH-DUDBRIDGE" FLAME-HEATED VAPORISER.

K Kerosene Supply from Pump. *B* Mixer.
HA Hot Air Chamber. *V* Vaporising Chamber.
M Lamp Chimney. *C* To Cylinder Inlet Valve.
T Ignition Tube. *L* Blow Lamp.

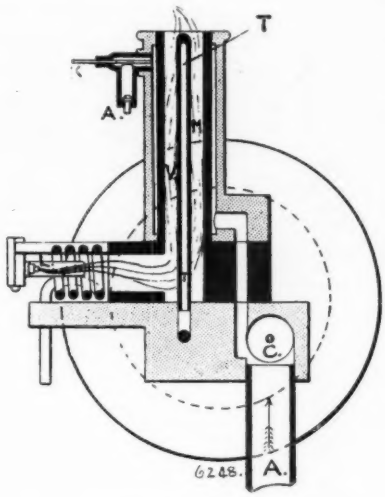


FIG. 21.—"CARTER-BLACKSTONE" FLAME-HEATED VAPORISER.

K Kerosene Supply. *A* Air Inlets.
V Vaporiser. *T* Ignition Tube.
M Lamp Chimney. *C* To Cylinder Inlet.
L Blow Lamp.

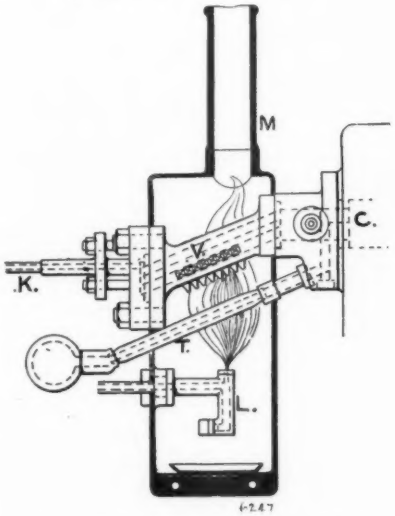


FIG. 20.—"HOWARD" FLAME-HEATED VAPORISER.

K Kerosene Supply from Pump.
V Vaporiser. *L* Blow Lamp.
T Ignition Tube. *C* To Cylinder Vapour Valve.

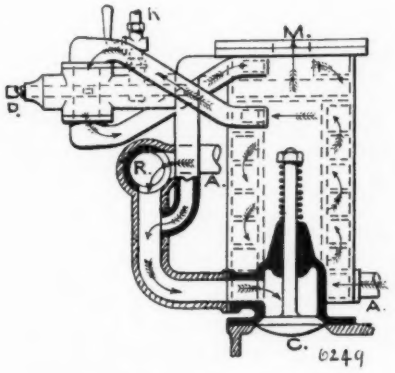


FIG. 22.—"ROOTS-VOSPER" FLAME-HEATED VAPORISER.

K Kerosene Supply. *A* Air Inlets.
P Sliding Feed Rod. *C* To Cylinder.
R Mixture Regulator. *M* Lamp Chimney.

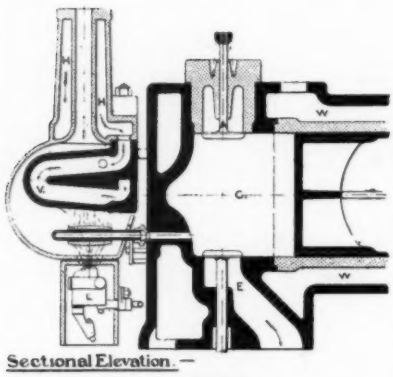


FIG. 23.—"CROSSLEY'S" FLAME-HEATED VAPORISER.

A Air Valve.	*C* Combustion Chamber.
H Hot Air.	*E* Exhaust.
W Water Jacket.	*O* Oil Measurer.
V Vaporiser.	O_1 Oil from Pump.
L Lamp.	O_2 Oil from Tank.

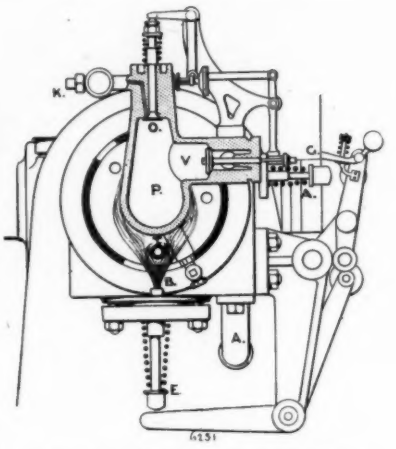


FIG. 24.—"GLOBE" FLAME-HEATED VAPORISER BY POLLOCK WHYTE AND WADDEL.

A Air Inlet Pipe and Valve.	*B* Blow Flame.
K Kerosene Supply.	*V* Supply Valve to Mixing Chamber.
O " Inlet Valve.	
E Exhaust Valve.	*P* Vaporiser.
T Ignition Tube.	*G* Governor.

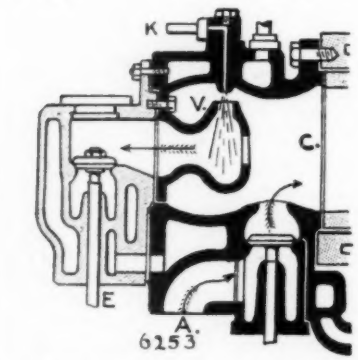


FIG. 27.—"NORRIS" EXPLOSION-CHAMBER VAPORISER.

K Kerosene Supply.	*E* Exhaust Outlet.
V Vaporiser.	*C* Cylinder.
A Air Inlet.	

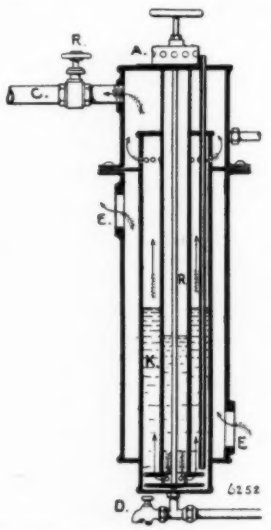


FIG. 26.—"MOORWOOD-BENNETT" EXHAUST-HEATED CARBURETTER.

K Kerosene Supply.	*A* Air Inlet.
E Exhaust Inlet and Outlet.	*C* To Cylinder.
R Supply and Mixture Regulators.	*D* Drain Cock.

being started and worked on petrol spirit or gas in order to get heated up to the temperature necessary for working on kerosene oil, or even on crude oil, in engines of large size. Volatilisers on the exhaust-heated system do not burn out or deteriorate, are easily cleaned and do not crack the oil mixture so as to result in the deposition of solids in the cylinder, and if used in combination with the inspirative feed method require no air nor oil-injection pump, the oil being supplied direct to a small cistern kept at constant level by a float or overflow control. This system lends itself to quickly responsive action on the throttle by a governor-controlled mixture supply. An atomised spray of water can also be fed into the mixture supply in proportion to the volume of air used, in the automatic and simple manner adopted for working on mineral spirit at starting (Fig. 18); the water-feed is useful in enabling a higher compression to be used without explosive shock and gives a decided advantage provided the water is sufficiently pure as not to leave a deposit in the explosion chamber ; a well-regulated water-feed results in a more even and perfect combustion of the vapour, and prevents that violent detonating effect produced in an oil-engine cylinder working with a heated volatilised mixture combined with high compression.

Engines using Flame-heated Vaporisers.

Class 7.—Engines of this class more nearly resemble the ordinary coal-gas engine and are usually governed on the well-known hit-or-miss system. These engines are generally provided with a sort of retort vaporiser heated by a blow-flame lamp, and oil is usually pumped in a "measured" quantity, at each induction stroke of the engine, into the vaporising space, which may be between the hollow walls of the lamp chimney, or this may be utilised solely to heat a current of air, the oil being vaporised, as in the Crossley and Howard engines (*vide* Figs. 20 and 23), in a retort tubular gasifier placed immediately over the ignition tube and flame. It is of high importance in this class of engine that the oil be delivered to the vaporiser in exactly measured charges. In the Dudbridge, Blackstone and Howard engines, special forms of oil force-pumps are relied upon for this purpose (Figs. 19, 20 and 21.). The Crossley engine, in addition to the pump, is fitted with a measuring cup, which is emptied at every induction stroke, so long as the governor causes the gas valve to the cylinder to open. In the Roots and Vosper engine (*vide* Fig. 22) no pump is used, the oil being fed by gravitation into a chamber fitted with a sliding rod, which is caused to move and carry with it, by means of a measuring cavity, a charge of oil into the mixing chamber at every induction stroke, the oil and air passing around a cellular hollow-walled lamp-chimney vaporiser before entering the cylinder. The Dudbridge and Blackstone engines have oil vaporisers within the lamp chimney, which is also provided with an air-heating space around the outer wall.

The Gardner engine is very similar, but governs by a hit-or-miss pump-action to the oil supply. In the Globe engine, made by Pollock, Whyte & Waddel, the vaporiser is fixed at the back of the explosion-chamber cover, and is provided with an oil and gas valve, both of which are simultaneously opened on the hit-or miss system by a tumbler governor, the admission of oil being controlled by a lift valve as in the Tangye and Campbell engines. Most of the engines of this class use an auxiliary current of heated air to mix with the oil spray in the vaporiser, as it permits of a lower temperature and tends to result in a clearer exhaust; it also sweeps out deposits of solids caused by the decomposition of the oil in some highly-heated vaporisers of this class. No engines of very large size have yet been constructed on this system, which depends entirely for the vaporising of the oil on the application of the external heat of a blow-flame lamp. The advantage possessed by this method, when adopted in engines of small and medium size, is very regular and economical working on light loads, approaching very nearly in this respect to the ordinary gas engine.

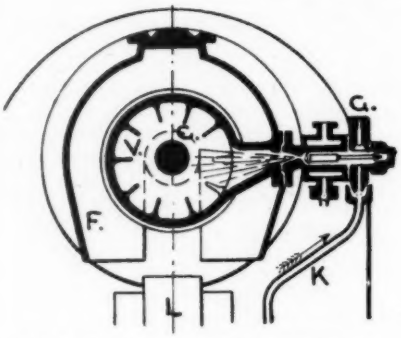


FIG. 28.—"HORNSBY-AKROYD" EXPLOSION-CHAMBER VAPORISER.

K Kerosene Pipe from Pump. *V* Vaporiser.
G Bye-pass Oil Governor Valve. *L* Starting Lamp.
C Narrow-neck Passage to Cylinder.

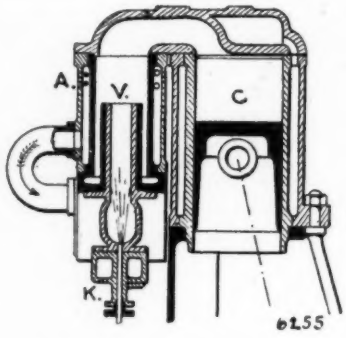


FIG. 29.—"GIBBONS" EXPLOSION-CHAMBER VAPORISER.

A Air Supply. *V* Vaporiser.
K Kerosene Supply. *C* Cylinder.

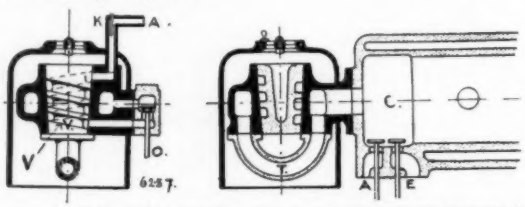


FIG. 31.—"RUSTON" (BARNE'S PATENT) EXPLOSION AND VOLATILISING-CHAMBER VAPORISER.

K Kerosene Supply. *A* Air Supply. *V* Volatilising Chamber. *T* Automatic Igniter.
E Exhaust. *C* Cylinder. *O* Vapour Valve.

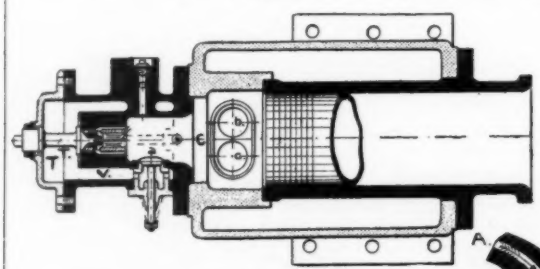


FIG. 30.—"CLAYTON-SHUTTLEWORTH" EXPLOSION AND VOLATILISING CHAMBER VAPORISER.

V Volatilising Chamber. *a* Vapour Valve.
T Automatic Igniter. *b* Exhaust Valve.
C Cylinder. *c* Air Valve.

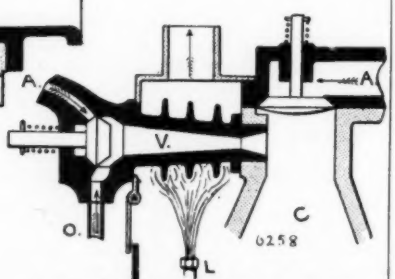


FIG. 32.—"CAPITAINE" EXPLOSION AND LAMP-HEATED VAPORISER.

V Vaporiser. *C* To cylinder. *A* Air.
L Lamp. *O* Oil.

Engines having an Exhaust-heated Carburetting Chamber.

Class. 8.—There are not many engines made on this system, which consists in either heating a supply of oil in a tank and drawing off the vapour, or by forcing air through heated oil, and thence to a mixing chamber, where it meets the main air supply. This principle is similar to the methods described in Class 1, with the addition of applied heat, and it cannot result in giving a very satisfactory working as the same drawback attaches to the heated oil carburettor as with the cold spirit-surface carburettor, and will always evaporate the lighter constituents first. When using kerosene oil it will frequently have to be cleaned out, the residuum being so much waste. The Moorwood-Bennett is the most recent application on these lines, and is illustrated by Fig. 26. The Hardy-Padmore engine has a surface large-wick carburettor, and is arranged close up to the hot breech end of the cylinder to assist in evaporation of the oil; this engine is only made, however, in very small sizes. Heating the oil, or both air and oil, has been tried by many engineers, and soon abandoned on being found unsuitable.

Engines having a Combined Vaporiser and Explosion Chamber forming part of the Cylinder-head.

Class 9. — The Akroyd-Stuart or Hornsby engine is the best example of this class, and runs steadily and well and is in no way dependent on external heating in ordinary working after once being started. The oil is injected direct into a vaporiser forming part of the explosion chamber, which communicates with the cylinder by a narrow neck (Fig. 28). The walls of the vaporiser portion of the explosion chamber are permitted to get heated to a dull red, the heat varying considerably according to the load, the temperature of the vaporiser being modified by an air jacket, and in large engines by water circulation. This engine gives good results, and is in very extensive use. The large single-cylinder engines of this type run successfully on filtered crude-oil.

Other engines coming under this class are the Norris, Gibbons, Hirsch-Low, Bryant, Torbensen, Tolch, Grob, Petter, etc. (Figs. 27—29). All these, except the last-named, use an oil force-feed injection pump that sprays direct into a vaporiser forming part of the explosion chamber, or, as in the Torbensen and Tolch engines, into an inner vaporiser surrounded by and open to the explosion chamber. Engines of this class are governed either by a cut-out on the oil-feed or by a bye-pass valve on the oil supply pipe under the control of the governor. The explosive action is, however, usually less forcible, and requires a somewhat larger cylinder than with engines in which the oil spray is drawn into the vaporiser together with a current of air, owing to a less perfect mixing of the vapour with the air charge.

Engines having a Vaporiser forming part of the Cylinder-head and surrounded either by a Volatilising Chamber or depending on external Flame-applied Heat.

Class 10.—There are several varieties of engines of this type, the best known using a vaporiser which forms part of the explosion chamber, and which is provided with a volatilising jacket around it. They are the Ruston (Fig. 31), the Clayton-Shuttleworth (Fig. 30), the Trusty and the Nicholson, etc. These engines, when warmed up to their work, are ordinarily self-igniting and dispense with a lamp. The oil is usually fed by an injection pump, but in the Ruston engine a new form of annular reciprocating cup is used, which avoids the uncertainty attaching to any form of pump. This special cup-feed is non-adjustable and places the engine beyond the liability of having its oil adjustment tampered with.

Other engines of this class have a volatilising chamber projecting within the vaporiser and explosion chamber, of which the Cundall engine is a fair example (Fig. 33).

Those engines depending for the most part on the flame of a blow lamp are:—the Tangye, Campbell, Fielding, Robey, Capitaine, etc. (Figs. 32 to 37), of which

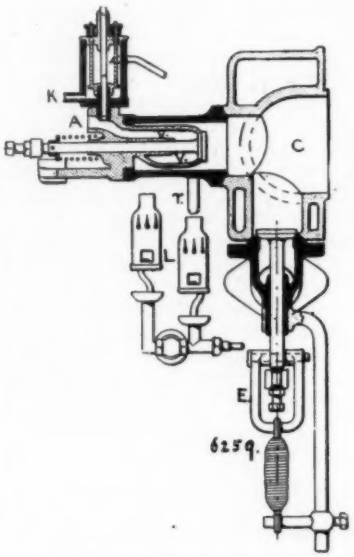


FIG. 33.—"CUNDALL" EXPLOSION AND VOLATILISING-CHAMBER VAPORISER.

K Kerosene Supply. *A* Air Supply.
V Volatilising Chamber. *T* Ignition Tube.
L Starting and Ignition Lamp. *E* Exhaust Valve.
C To Cylinder.

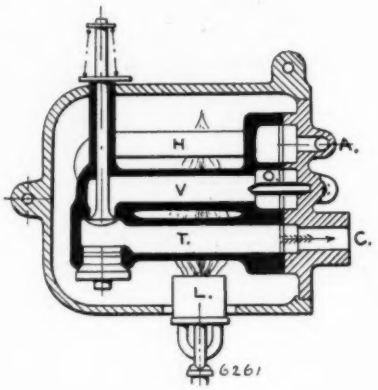


FIG. 35.—"FIELDING" EXPLOSION AND LAMP-HEATED VAPORISER.

A Air Inlet. *L* Lamp.
H Hot Air Tubes. *O* Oil Jet.
V Vaporiser Tube. *C* To Cylinder.
T Ignition Tube.

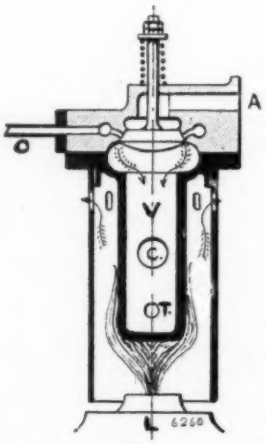


FIG. 34.—"CAMPBELL" EXPLOSION AND LAMP-HEATED VAPORISER.

A Air. *O* Oil. *L* Lamp. *V* Vaporiser.
C To Cylinder. *T* Ignition Tube.

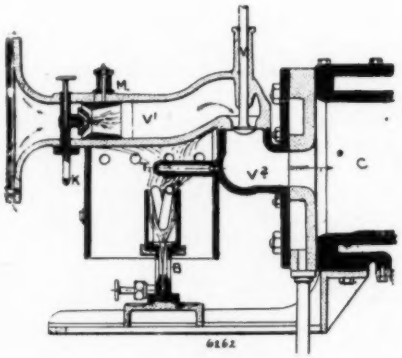


FIG. 36.—"ROBEY" VAPORISER.

A Air Inlet.
K Kerosene from Pump.
M Air Regulator.
*V*¹ Lamp-heated Vaporiser.
*V*² Explosion-heated Vaporiser.
C Cylinder.
T Ignition Tube.
B Blow-flame Lamp.

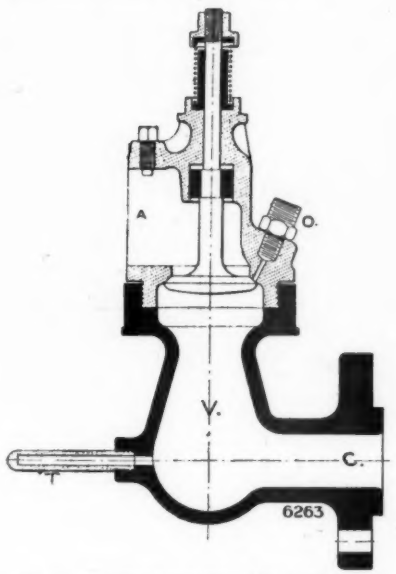


FIG. 37.—"TANGYE" EXPLOSION AND LAMP-HEATED VAPORISER.

A Air Inlet. *O* Oil Inlet. *V* Vaporiser.
T Ignition Tube. *C* To Cylinder.

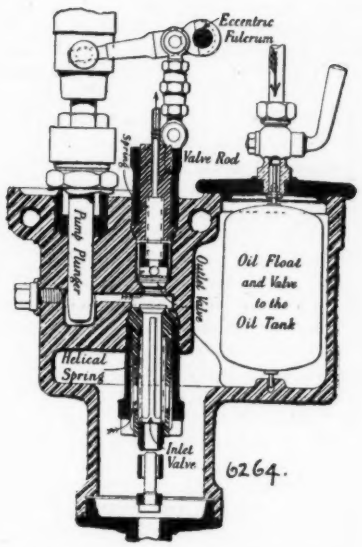


FIG. 38.—"DIESEL" HIGH COMPRESSION ENGINE. OIL SUPPLY PUMP WITH FLOAT FEED.

the first two use a gravitation oil feed, and the others a pump-injection feed. All are governed by a trip cut-out gear on the exhaust valve, and when a pump is used this is simultaneously put out of action at the same moment. This method is used to avoid cooling of the vaporiser by indraughts of cold air. Many engines of considerable power have been made of this simple type, and under favourable circumstances they are very economical and little dependent on external heating.

Engines Vaporising by High Compression.

Class II.—These require a comparatively long stroke and extremely well-fitting pistons and valves in order to obtain without leakage the necessary compression for spontaneous combustion, so as to avoid the necessity for external heating of any sort, either before or after starting. To obtain this result an air-compression of from 30 to 35 atmospheres is necessary, and into the air-charge thus dynamically heated to a high degree is injected the atomised feed of oil, during the first quarter or so of the working stroke. This class of engine requires an auxiliary air-pump to compress air necessary for atomising the oil as it is being injected into the cylinder; the necessary pressure for this purpose being from 45 to 50 atmospheres. The air and oil are forced past a cam-opened spraying-valve against the pressure in the cylinder at a high velocity, so as to thoroughly atomise and mix it with the cylinder compressed-air charge. The resultant combustion is slow and continuous for a considerable portion of the stroke, and forms the most favourable feature of the engine. The oil pump has a variable stroke under the control of the governor, and is fed from a cistern kept at constant level by a float regulator as used in the high-speed petrol engines, and the supply-valve of the pump is worked by a cam action, as in the old Spiel engine (Fig. 38). Great difficulty is found in maintaining in working order the mechanism of the pump and spraying-valve, owing to the extremely high pressures used, and to

minute impurities in the oil, to clogging of the spraying-valve owing to the heat from combustion, and to leakage.

This type of engine, better known as the "Diesel," has been exploited by a number of manufacturers, each with the hope of obtaining in practice the results promised by theory, such as (1) being able to work on coal-dust; (2) the elimination of water cooling for the cylinder walls; (3) the construction of an engine which, while having no compensating disadvantage, should work without a vaporiser and igniter; (4) a higher economy of fuel than by any other known means. In some special instances most favourable results have been obtained, which, if continued in practical working, would place this class of engine above all others, provided the drawbacks of first cost, deterioration, and uncertainty of working under uniform efficiency were not experienced. Although coal-dust cannot be used, it is found possible to work this engine on carefully filtered crude-oil, and if built in much larger sizes it is probable that the difficulty of dealing with the very high pressures would not be so prejudicial to its use, making it possible also for even superior results to be obtained in economy.

Possibilities for Larger Powers.

There is no practical reason why single-cylinder engines, from 100 h.p. upwards to even 1,000 h.p., and using filtered crude oil, should not be constructed. The consumption of oil in an engine of 1,000 h.p., for instance, would not exceed 45 gals., or less than 400 lbs. per hr. at full load, and as crude oil is already obtainable in large quantities from reliable sources at a cost of less than £3 per ton, delivered to the engine tank, it will be seen that these figures favour the natural-oil explosion engine against the best steam engine using coal at 10*s.* per ton delivered to the boiler stack.

The size and weight of the oil engine would not exceed that of a good three-cylinder compound steam engine of equal power, leaving out of consideration the weight and space occupied by bunkers and boilers.

Multicylinder engines of more than 100 h.p. are already successfully applied to the propulsion of launches, submarine boats, etc., using the comparatively expensive mineral spirit; the remarkable results recently obtained by the Napier, Thorneycroft, and Mercedes spirit-explosion motor launches being well-known.

With the practical development of the heavy-oil explosion engine in really large sizes, and capable of working continuously, the propulsion of battleships and vessels of the mercantile marine by this means would be possible, and carry with it the advantage of effecting a saving of the time now occupied in coaling, and further, of making it possible to entirely avoid that conspicuous smoke exhalation so inseparable with steamships under present conditions. Further, the adoption of the oil engine as a means of propulsion would mean the elimination of the steam boiler, which all would welcome who have had any experience at sea.

The possibility of ships being able to sail from London to Melbourne without having to waste time in refuelling on the way, presents another of the many advantages that will accrue from the more extensive development of the natural-oil marine explosion engine.

Rapid-Cutting Steel Tools and the New Tool Steel.*

THE issue of the final instalment of the tables of results obtained from experiments with rapid-cutting steel tools, made under the supervision of Dr. Nicholson of the Manchester Municipal School of Technology, affords a suitable opportunity for reproducing the substance of an interesting paper† in which the history of the new tool-steel is traced, and the effect that it has had on modern shop methods.

Manufacturing, in the modern and best sense of the word, has, we may fairly say, had its birth in the last half of the nineteenth century. For the past forty years or more there was a well-defined discontent among men of progressive ideas with the methods in vogue and the results obtained in general machine-shop practice. The opinion prevailed that the product of none of the machines in use was up to a standard commensurate with their cost and maintenance. What should the remedy be? As so often happens in such instances, some invention was sought for which would be revolutionary in character, and which never comes. Many suggestions were made; some of them wise and some otherwise. Of the latter class may be mentioned the abrading wheel to grind off the stock, and the cold saw to tear it off, in place of the cutting-tool to pare it off, as it was and is used with all of the machine tools.

In the early days, while we were making things, and before we had learned how to manufacture, the lathe was the all-around tool of the shop, and it was made to do much work which could have been more expeditiously done on a surfacing machine, which then was not in existence. But with the demand for it the planer soon came forth, and it was followed by the shaper and the milling-machine. As these tools came into general use, the necessity of further increasing the product and reducing the cost again became pressing, and it forced the process of segregation on until we were given the screw-machine, the turret-lathe, the boring-mill, the pulley-lathe, and the automatic gear-cutter. All of these tools were made heavier and larger year by year, until their limit of production was reached, not on account of the machine itself, but on account of the tool steel then to be found in the market. It is not certain that this steel was wholly to blame for some of the failures which are charged against it, but it is probable that a part of them at least were due to lack of knowledge in handling. It was a fact, nevertheless, that in many of the new machines the steel would not stand up to the larger demands put upon it; and so a blank wall seemed to rise up and bar further progress, which, to a certain extent, it has controlled for the last quarter of a century. Some increase in the output of these machines was obtained by the use of cooling mediums, such as water, oil and alkaline solutions, which were allowed to flow on the tools at the cutting-points, and so carry off some of the heat; and this practice still obtains in some lines of work.

In the efforts to increase the product of the machines as they became more powerful, they were driven at higher speeds, with greater depth of cut and faster feeds, until the heat produced at the tool point caused it to break down, and it was found that the limit of temperature for the carbon steel was from 450 to 500 degs.

In the early practice, to harden steel for tools, we were instruced to heat it to "a cherry red," cool in water, clean off the hardened surface, and again heat until by oxidation the light colour was succeeded by shadings from a light yellow to a dark blue, this colour indicating a low temper. That the "cherry-red" temperature, as measured by the eye, was a very large uncertainty, may at once be suspected. It may well be doubted if any two persons could measure it alike within a hundred degrees, and the same operator could not do it on two different days if one were clear and the other cloudy. This feature has come to be so well recognised in the large establishments where much hardening and tempering is to be done that a room is provided for it with curtains on the windows, so that a uniform light shall be secured. It used to be thought necessary to make the steel harder than was required for any particular service, and then reduce it as before described. The later and better

* Continued from page 237.

† *The New Tool Steel.* Prof. C. I. King, in *The Wisconsin Engineer.*

TABLE XX.—ENDURANCE

Intended length of run: Two hours.

No. of Trial.	Description of Tool Steel used.	Intended Speed Ft. per min.	Actual Speed.	Actual Cut.	Actual Traverse.	Area of Section of Cut.	Duration of Trial.
191	High-speed Air Hardened ...	90	93·0	0·183	0·0625	·001143	120·0
194	Do. do. ...	90	89·8	0·191	0·0625	·001193	64·87
*195	Do. do. ...	90	89·0	0·1875	0·0625	·001172	16·73
197	Do. do. ...	90	90·5	0·188	0·0625	·001175	120·0
198	Do. do. ...	90	97·0	0·190	0·0625	·001187	120·0
199	Do. do. ...	90	87·7	0·190	0·0625	·001187	14·82
200	Do. do. ...	90	90·0	0·187	0·0625	·001168	120·0
*201	Do. do. ...	90	92·0	0·185	0·0625	·001155	16·73
	Averages.....					·001172	
196	Ordinary Mushet	45	43·0	0·192	0·0625	·001199	78·83
192	Ordinary Water Hardened ...	22½	24·0	0·175	0·0625	·001093	9·117
193	Do. do. ...	22½	22·8	0·174	0·0625	·001087	28·6
202	Do. do. ...	22½	23·0	0·190	0·0625	·001187	10·6
203	Do. do. ..	22½	22·5	0·188	0·0625	·001175	23·6

* 201 same Tool as 195 reforged and tempered and tried again.

TABLE XXI.—ENDURANCE TRIALS

Intended length of run: Two hours.

204	High-speed Air Hardened ...	44	42·3	0·189	0·0625	·001181	10·0
205	Do. do. ...	40	39·0	0·189	0·0625	·001181	31·0
209	Do. do. ...	40	36·2	0·1875	0·0625	·001171	6·0
210	Do. do. ...	40	39·0	0·1875	0·0625	·001171	9·0
211	Do. do. ...	36	34·4	0·181	0·0635	·001130	69·0
212	Do. do. ...	36	33·8	0·1875	0·0625	·001171	3·5
213	Do. do. ...	36	34·2	0·1875	0·0625	·001171	2·15
214	Do. do. ...	36	34·2	0·1875	0·0625	·001171	60·0
215	Do. do. ...	36	33·7	0·185	0·0625	·001156	19·0
216	Do. do. ...	36	34·2	0·1875	0·0625	·001171	3·0
217	Do. do. ...	36	35·2	0·1875	0·0625	·001171	1·73
218	Do. do. ...	36	35·1	0·178	0·0625	·001112	62·0
219	Do. do. ...	36	35·5	0·179	0·0625	·001118	33·0
	Averages.....					·001159	
208	Ordinary Mushet	20	19·5	0·189	0·0625	·001181	60·0
208a	Do.	25	22·5	0·1875	0·0625	·001171	5½
206	Ordinary Water Hardened...	12½	12·0	0·189	0·0625	·001181	3·45
207	Do. do. ...	12½	10·3	0·189	0·0625	·001181	9·0

practice is to use a lower hardening temperature, thereby avoiding the second process, and there need be little doubt that from 10 to 15 per cent. more work might have been obtained from this steel had we better known how to handle it at the forge.

With all of the desire and effort on the part of the manufacturing world to increase the output of the tools in use, it is a curious fact that it allowed a new steel to lie within its grasp for nearly forty years without recognition of its value, and which, if properly used, would have increased its product from 25 to 40 per cent. The new product was

TRIALS ON SOFT STEEL.

Intended cut, $\frac{3}{16}$ in.; traverse, $\frac{1}{8}$ in.

Reason for Stopping.	Area Machined in square feet. Total.	Per min.	Weight Removed in lbs. Total.	Per min.	Gross E.H.P.	Friction H.P.	Net H.P.	Cutting Force lbs.	Motor Speed Gear and Cone Step.
Time up	58·0	0·483	451½	3·76	12·93	5·92	7·01	2,356	170
Tool failed	30·3	0·466	236	3·64	17·15	8·88	8·27	3,080	250
do.	7 73	0·462	57¾	3·45	17·10	9·4	7·70	2,920	250
Time up	56·54	0·471	431	3·59	16·64	9·46	7·18	2,620	270 Dm.
do.	59·70	0·4975	460¼	3·84	15·36	8·26	7·10	2,440	210 Ds.
Tool failed	6·76	0·456	50	3·37	14·40	8·64	5·76	2,170	200
Time up	62·32	0·463	425·5	3·55	14·50	8·38	6·12	2,250	205 Ds.
Tool failed	8·02	0·479	60	3·58	18·90	10·43	8·47	3,040	215
								2,609	= 98·5 tons per sq. in.
Tool failed	17·84	0·226	136¾	1·735	10·8	6·46	4·34	3,100	
do.	1·14	0·125	8¼	0·905	15·2?	9·03?	6·17?	8,480?	250
do.	3·395	0·119	24½	0·858	11·15	9·03	2·12	3,050	250
do.	1·265	0·119	9	0·85	10·9	8·25	2·65	3,800?	220 Tm.
do.	2·76	0·117	20½	0·87	10·35	7·38	2·97	4,350?	222

ON MEDIUM CAST IRON.

Intended cut, $\frac{3}{16}$ in.; traverse, $\frac{1}{16}$ in

Tool failed	2·20	0·220	14½	1·425	11·22	7·82	3·40	2,650	215 Ts.
do.	6·29	0·203	43½	1·44	9·63	7·17	2·46	2,075	200 ,,
do.	1·13	0·190	6½	1·08	11·60	8·30	3·30	3,100	205 ,,
do.	1·83	0·203	11½	1·28	9·90	7·75	2·15	1,820?	202 ,,
do.	12·50	0·181	82	1·19	11·45	8·23	3·22	3,082	260 Tm.
do.	0·615	0·176	2⅞	0·822	10·72	8·23	2·49	2,430	260 ,,
do.	0·40	0·186	1¾	0·813	10·60	8·40	2·20	2,120	260 ,,
do.	10·66	0·177	73⅝	1·225	10·83	7·92	2·91	2,340	263 ,,
do.	3·34	0·176	22½	1·18	10·4	7·5	2·90	2,840	260 ,,
do·	0·53	0·178	3	1·0	10·7	8·2	2·5	2,410	260 ,,
do.	0·32	0·183	1¼	0·72	14·0	11·15	2·25	2,680	270 ,,
do.	11·40	0·184	75⅝	1·22	12·3	8·7	3·6	3,380?	275 ,,
do.	6·12	0·185	39½	1·20	11·6	9·0	2·6	2,420	284 ,,
								2,565	= 99 tons per sq. in.
End of run	6·1	0·106	41½	0·69	7·75	6·2	1·55	2,620	200 Tl.
Tool failed	0·63	0·115	3¾	0·681	9·8	8·4	1·4	2,050	260 ,,
do.	0·215	0·062	¼	0·072	...	...	...	...	152 ,,
do.	0·485	0·054	2¾	0·30	5·67	4·53	1·14	3,650?	140 ,,

known in the market as Mushet steel, being named after the inventor. Mushet was an Englishman who lived in the Forest of Dean, a locality where much of the charcoal used by the Sheffield mills was made. With the aid of a steel-maker named Brookfield he produced the new alloy which was said to contain 2 to 3 per cent. of carbon, and 8 to 10 per cent. of tungsten. The first alloy of tungsten and iron dates back to 1773, and d'Elhuyar and Beirthier are accredited with its production; but at that date it attracted no attention in the industries.

There are two reasons why this steel did

TABLE XXIII.—HARDNESS TESTS.

No. of Trial.	Time.	Duration.	Counter Readings.	Total Revolutions.	Height of Drill.	Figure of Hardness.	
		Min. Sec.					
1	2-40-35		822		4·485		
	2-41-27	0 52	1,059	237	3·985	4·74	Standard Specimen.
2	2-58-3		545		4·485		
	2-58-42	0 39	737	192	3·985	3·84	Whitworth's Soft Cast Iron.
3	3-4-7		82		4·485		
	3-5-0	0 53	333	251	3·985	5·02	Whitworth's Medium Cast Iron.
4	2-13-55		692		4·485		
	2-14-45	0 50	943	251	3·985	5·02	Standard Specimen.
5	3-22-5		422		4·485		
	3-23-38	1 33	972	450	3·985	9·00	Whitworth's Hard Cast Iron.
6	3-37-35		800		4·485		
	3-39-15	1 20	1,196	396	3·985	7·92	Standard Specimen.
7	9-37-40		921		3·970		
	9-38-27	0 47	1,133	212	3·470	4·24	Standard Specimen.
8	9-42-43		430		3·970		
	9-43-30	0 47	640	210	3·470	4·20	Standard Specimen.
9	9-51-55		172		3·970		
	9-53-8	1 13	525	353	3·470	7·06	Whitworth's Soft Steel.
10	9-58-30		5		3·970		
	9-59-45	1 15	358	353	3·470	7·06	Whitworth's Medium Steel.
11	10-6-30		918		3·970		
	10-7-15	0 45	1,128	210	3·470	4·20	Standard Specimen.
12	10-17-44		653		3·970		
	10-19-6	1 22	1,055	402	3·470	8·04	Whitworth's Hard Steel.
13	10-20-45		595		3·970		
	10-22-12	1 27	1,039	444	3·470	8·88	Whitworth's Hard Steel.
14	10-32-35		710		3·970		
	10-33-23	0 48	945	235	3·470	4·70	Standard Specimen.

not get into extensive use at an earlier date; one, its cost was 1*s.* 8*d.* to 1*s.* 10*d.* per pound as compared to the carbon steel at 3*d.* to 10*d.* The other reason, and by no means the least, was due to the great difficulty in forging it to the required shapes, for if not heated and forged properly by the blacksmith it would break and go to pieces as easily as cast-iron.

A striking characteristic of the tungsten steel was that it did not have to be hardened: it was always hard when cold, and it could not be annealed. It, however, possessed that quality of structure which enabled it to stand from 600 to 700 degs. of temperature before it would break down. This new steel came later to be known as self-hardening steel, and as air-hardening steel, from the fact that if subjected to an air blast its lasting qualities were enhanced to a small degree. The usual surface velocities at which the carbon steel was used varied from 15 to 25 ft. per minute, while the tungsten steel would stand from 40 to 80 ft.

On a fractured surface the tungsten steel shows a very close structure; it is darker in

colour than the carbon steel, and in grinding on an emery wheel it gives off a dark red spark like cast-iron, while the other grade shows a bright and scintillating spark. For many years it was supposed that the function of the tungsten was to hold a larger percentage of the carbon in the combined form, and therefore the steel-maker always furnished the toolsmith with positive instruction to work it at a low temperature, and this direction was carefully followed.

Up to comparatively recent dates, all of this steel was imported from England. Finally American manufacturers began to produce it, and while their first attempts were far from successful the American product now is not excelled by any other.

About four years ago a discovery was made which marked a long step in advance in the use of these steels for cutting purposes. Presumably by accident, a tungsten steel tool was heated up to the point of combustion or to the melting point. After cooling off it was put in service, and it caused general surprise by showing much higher efficiency than was ever before attained by any steel. This incident was brought to the attention of a couple of young men, one a chemist, the other an engineer in the employ of the Bethlehem Steel Company, who at once began a series of experiments to determine the cause for these unexpected results. So far as it is known this has not been found, but they did discover some method of treatment, which is still a trade secret, by which the steel could safely be raised to this high temperature and still be on a commercial basis. After this new treatment it was found that the tools would stand from 1,100 to 1,200 degs. of temperature before failure occurred.

This discovery opened an immense field for improvement along nearly all manufacturing lines, and it also developed the rather astounding proposition, that to get the full benefit of it, all machine tools with which the new steel should be used, must be designed and built especially for it. It was speedily found that none of the tools in use were heavy enough to withstand the extra strain, neither had they sufficient driving power for the increased cuts which the new steel would stand.

That a clearer perception may be had of what this portends, it may be stated that the standard machine tools of average size require from one to six horse-power to drive them, while new tools already in the market, and designed especially for this steel, have at a maximum used 50 h.p.

In the series of experiments made at the works of the Bethlehem Steel Company to prove the value of the new process, 200 tons of forgings were used, and £20,000 were expended. Many large forgings are made by this company, and in their production much time and fuel are required, and many men are necessary to handle them; by the old method these forgings were brought as nearly as possible to finished sizes before machining; now they are made only to approximate sizes, and the lathe and one or two men do the rest, and forgings of 36 ins. in diameter have been reduced to 28 ins. at one cut.

As a result of this recently-acquired knowledge, line shaft speeds have been increased from 90 to 250 revolutions per minute; cutting speeds are increased 180 per cent., depth of cut 30 per cent., and the rate of feed by 24 per cent., and the end is not yet in sight. The planing-machine and shaper will probably be the last of our tools to succumb to the new conditions, but we may not be surprised to see them driven at speeds approaching 100 ft. per minute in the near future.

In contemplation of these results the question at once arises: what has caused this wonderful mutation in the structure or chemistry of the alloy? Frankly, no one knows, and, for the present at least, we must be contented with the results obtained. It is known that where the steel contains small percentages of chromium and carbide of chromium, the last-named element is reduced in quantity by about one-half after the steel is treated. Analyses of what are called the burned portions of the steel showed that nearly all of the carbon has been burned out, and the inference was at once drawn that the carbon was not necessary, and so in the new steels only ·5 to ·6 per cent. is left in.

It may be of some interest to state that the original Mushet steel, when worked at the cherry-red temperature of 1,450 to 1,550 degs., gave what was supposed to be its greatest possible service. Between this and 1,700 degs. the value rapidly fell to nearly zero, but from this point up to 1,900 degs. it rises sharply to the maximum. It also has been found that some of the new product can be annealed so that it can be machined, and some of it is soft when sent from the mills; this, of course, opens up a much larger field for its use, and makes it available for milling-cutters, dies, drills, etc. Curiously enough, it will not stand shock and jar, and therefore is not suitable for cold chisels, stone-drills, or any of that class of work.

It also fails in use for finishing work in the machines, where the carbon steel succeeds. Its greatest success has been found in roughing work, and, without seeing, it is difficult to believe that it will render service after the

TABLE XXIV.—ELASTIC CONSTANTS AND ULTIMATE TENSION.

1 MATERIAL.	2 No. of Bar.	3 Diameter of Bar.	4 Area of Bar.	5 Modulus of Elasticity.	6 Elastic Limit.	7 Yield Point.	8 Maximum Stress.
		Inches.	Sq. ins.	Lbs. per square inch.	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.
Soft Steel	1	0·623	0·305	29,990,000	6·56	11·47	26·60
Do.	2	0·623	0·305	29,860,000	8·20	13·93	25·93
Do.	3	0·623	0·305	29,990,000	7·38	13·11	26·33
Medium Steel ...	7	0·622	0·304	30,330,000	6·58	9·87	28·75
Do.	8	0·622	0·304	30,330,000	6·58	9·87	28·91
Do.	9	0 623	0·305	30,000,000	6·56	9·83	28·99
Hard Steel	13	0·622	0·304	30,385,000	13·16	19·74	46·83
Do.	14	0·623	0·305	30,100,000	13·11	19·67	46·83
Do.	15	0 621	0·303	30,233,000	13·25	19·80	46·49
Soft Cast Iron ...	19	0·621	0·303	8,460,000	.....	.....	6·01
Do.	20	0·619	0·301	8,620,000	.....	.....	5·52
Do.	21	0·620	0·302	8,134,000	.....	.....	5·51
Medium Cast Iron...	25	0·618	0·300	14,300,000	.....	.....	11·46
Do.	26	0·621	0·303	14,300,000	.....	.....	11·45
Do.	27	0·621	0·303	14,500,000	.....	.....	10·85
Hard Cast Iron ...	31	0·621	0·303	14,850,000	.....	.....	7·61
Do.	32	0·621	0 303	14,810,000	.....	.....	7·32
Do.	33	0·623	0·305	14,500,000	.....	.....	9·02

temperature has risen until both the tool-point and the shaving are red.

Apparently the higher the temperature to which the steel can be raised in treating it for use, without melting it, the higher the temperature it will stand in service.

Molybdenum is also used to produce an air-hardening steel in place of the tungsten, only about one-half of the quantity in weight being necessary to obtain the same result, and in some of the steels both of these materials are used.

The manufacturers state that the high prices for the new product are due largely to the difficulty in getting a homogeneous alloy, owing to the greater specific gravity of the tungsten and molybdenum. Neither of these alloys is so efficient in use on cast-iron as on the forged stock, yet they excel the carbon product by 25 or 30 per cent.

STRENGTHS OF MATERIALS OPERATED UPON.

	COMPRESSION.								
	9	10	11	12	13	14	15	16	17
	Per cent. Extension on 4 in.	Per cent. Reduction in area.	No. of bar.	Diameter of bar.	Area of bar.	Length of bar.	Modulus of Elasticity.	Stress per square inch.	
								Elastic Limit.	Yield Point.
	28·8	54·8	4	1·247	1·221	2·50	29,790,000	6·55	11·46
	21·2	37·1	5	1·247	1·221	2·50	30,180,000	5·73	12·27
	24·5	44·3	6	1·247	1·221	2·50	30,580,000	6·14	11·40
	26·5	37·5	10	1·247	1·221	2·50	29,660,000	4·91	10·24
	25·4	36·5	11	1·247	1·221	2·50	301,75,000	4·91	10·24
	25·0	37·7	12	1·247	1·221	2·50	30,175,000	4·91	9·82
	13·5	20·0	16	1·140	1·021	2·50	30,860,000	9·79	20·57
	14·5	18·0	17	1·141	1·023	2·50	30,750,000	9·78	20·53
	11·5	10·5	18	1·140	1·021	2·50	30,610,000	9·79	20·57
								Crushing Stress. Tons per sq. inch.	
	.....	.....	22	1·247	1·221	2·50	8.500,000	28·61	
	.....	.....	23	1·248	1·223	2·50	8,170,000	25·76	
	.....	.....	24	1·247	1·221	2·50	9,040,000	26·38	
	.....	.....	28	1·248	1·223	2·50	13,700,000	43·90	
	.....	.....	29	1·247	1·221	2·50	14,150,000	44·00	
	.....	.....	30	1·247	1·221	2·50	14,070,000	44·00	
	.....	.....	34	1·244	1·215	1·250	14,670,000	39·67	
	.....	.....	35	1·248	1·223	1·250	14,350,000	45·07	
	.....	.....	36	1·247	1·221	1·250	14,600,000	45·71	

NOTES ON LOCOMOTIVE & RAILWAY ENGINEERING

By CHARLES S. LAKE.

The New 4-4-2-Type Engines on the North-Eastern Railway.

THIS subject was briefly referred to in the Notes for February, when a diagram, accompanied by a few leading particulars of the interesting locomotive illustrated herewith was presented. The design is in every sense a striking one, as will be gathered from the perspective view of the engine, whilst the construction in detail may also be followed to a great extent by referring to the general arrangement drawing, also reproduced.

The engine is built to what are practically maximum dimensions throughout for this country, and it can be at once seen that every provision has been made to render it capable of dealing with the heaviest probable loads, whilst retaining a margin of power which may be utilised if and when required.

The boiler, together with the firebox, provides 2,455·8 sq. ft. of heating surface, with a grate area of 27 sq. ft., which dimensions are fully adequate for maintaining steam at the pressure adopted, viz. 200 lbs. per sq. in., even when the exceptional proportions of the cylinders—20 ins. by 28 ins.—are taken into account.

The axle of the carrying wheels is placed well in underneath the firebox, which necessitates the ashpan being arched to clear it. These wheels are provided with outside bearings, the framing being double at this point. The valve-gear is of the Stephenson link pattern, and segmental steam distributing valves on W. M. Smith's system are employed.

Steam-reversing gear is provided. The steam and water cylinders are secured to a cross-stay plate bolted to the frames between the coupled axles. These cylinders are not visible in the completed engine, owing to their being fixed immediately below the boiler barrel midway between the frames.

The springs of the coupled wheels are connected together by an equalising beam, as is frequently done in American practice, in which matters are usually carried a step further with this type of engine by "compensating" the trailing-wheel springs as well as the others.

With the introduction of these engines the North-Eastern Railway Company now possess three distinct types of coupled express locomotives, each capable of dealing with heavy loads at high average speeds. These are the 4–4–0, 4–6–0, and the present 4–4–2 types; thus every opportunity exists for ascertaining the relative merits of each from an operative and economical standpoint, after due regard has been had to considerations of first cost of construction, weight for weight, the amount of tractive power theoretically credited to each pattern, and other matters coming within the scope of comparison. The writer's thanks are due to Mr. W. Worsdell for the photograph, drawings, and particulars reproduced.

The leading dimensions are as follows :—

	Ft.	ins.
CYLINDERS—		
Diameter of cylinders	0	20
Stroke of piston	0	28
Lap of valve	0	1¼
Maximum travel of valve	0	4 11/16
WHEELS (Steel)—		
Diameter of driving wheels	6	10
Diameter of bogie wheels	3	7½
Diameter of carrying wheels	4	0
BOILER—		
Centre of boiler from rail	8	11
Length of barrel	15	10½
Diameter of boiler (outside)	5	6
Thickness of plates	0	0⅝
FIREBOX—		
Length outside	9	0
Breadth outside at bottom	3	11
Depth below centre line of boiler at front end	6	4
Depth below centre line of boiler at back end	5	4
INSIDE FIREBOX (Copper)—		
Length at the bottom side	8	3½
Breadth at the bottom side	3	2½

		Ft.	ins.
TUBES (Steel)—			
Number of tubes	268		
Length of tubes between tube plates		16	2⅝
Diameter outside		0	2
Thickness	No. 12 W.G.		
Heating surface in tubes	2275·8 sq. ft.		
Heating surface in firebox	180·0 ,,		
Total	2455·8 ,,		
Area of fire grate	27 ,,		

	T.	cwts.	qrs.
WEIGHT OF ENGINE IN WORKING ORDER—			
On bogie wheels	16	10	0
On leading wheels	19	10	0
On driving wheels	19	10	0
On trailing wheels	16	10	0
Total	72	0	0
WEIGHT OF TENDER IN WORKING ORDER—			
On front wheels	14	10	0
On middle wheels	13	10	0
On trailing wheels	15	10	0
Total	43	10	0

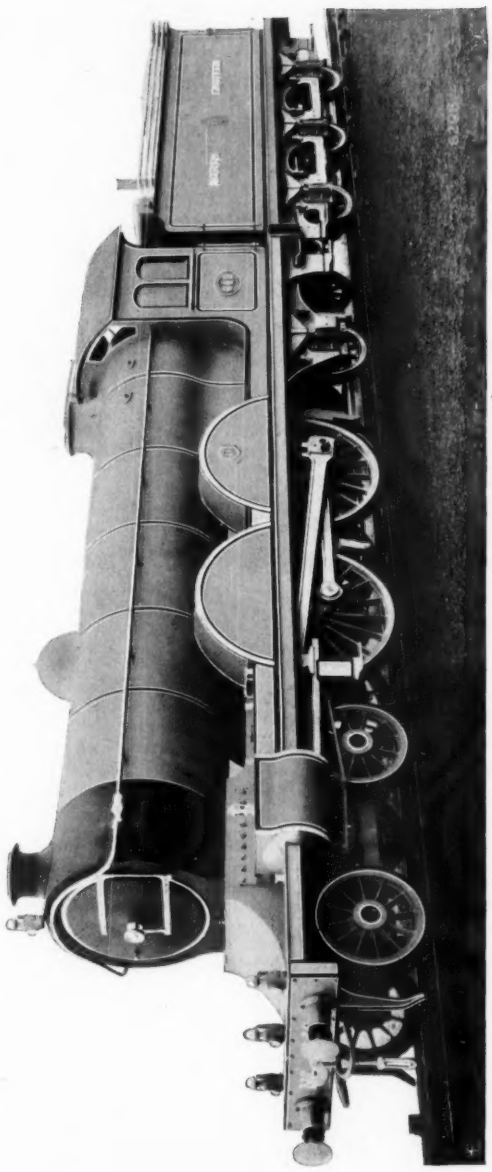
TENDER—	
Capacity of tank	3,669 galls.
Capacity of well	456 ,,
Total	4,125 ,,
Coal space	5 tons

The Future of the Compound Locomotive in Great Britain.

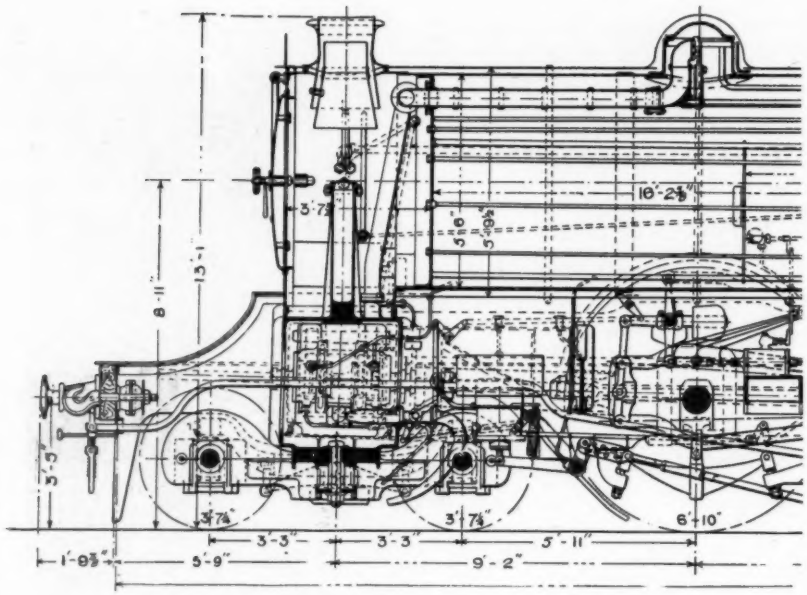
WHEN commenting upon the position of the compound locomotive in the first issue of these Notes,* the writer made special reference to the popularity of this type abroad and unpopularity in this country. Since that date matters have altered but little. In the United States and upon the Continent engineers continue to increase the number of compound locomotives, while in Great Britain the opposite methods still prevail.

The latest and largest locomotives upon the North-Eastern, Great Northern, and other railways are non-compounds, and, what is still more noteworthy, the newest additions to the London and North-Western locomotive stock are also to be simple engines, designed by Mr. Whale, whose lengthy association with Crewe Works and Mr. Webb's methods has not had the effect of ensuring the perpetuation of the latter.

* *Feilden's Magazine*, August, 1903, p. 124.



4-4-2-TYPE EXPRESS LOCOMOTIVE, NORTH-EASTERN RAILWAY.



DETAILS OF 4-4-2-TYPE EXPRESS LOCOMOTIVE, NORTH-EASTERN RAILWAY.

Against the foregoing we have to set the fact that the Midland authorities have increased the number of their compound locomotives, bringing up the total to five engines in all; but their locomotive superintendent has also retired, and it is not definitely known that his successor will continue in the same policy, although rumour has it that this may be expected.

Perhaps the most hopeful direction in which supporters of the compound principle in this country may look, is that of the Great Western experiments with the de Glehn system. Time will provide the outcome of the trials which are being made, and whatever data is published will provide a clue to the future prospects of this type of engine in Great Britain, for it is only reasonable to assume that if the results are as favourable here as they have consistently been upon the Continent, we may expect to see it more or less largely introduced.

Private Owners' 20-Ton Wagons.

FOLLOWING upon the information already published with regard to this subject, drawings and particulars of the bearing springs and various ironwork details for the above wagons are presented herewith.

Clause 13 in the Clearing House committee's specification is to the effect that :—

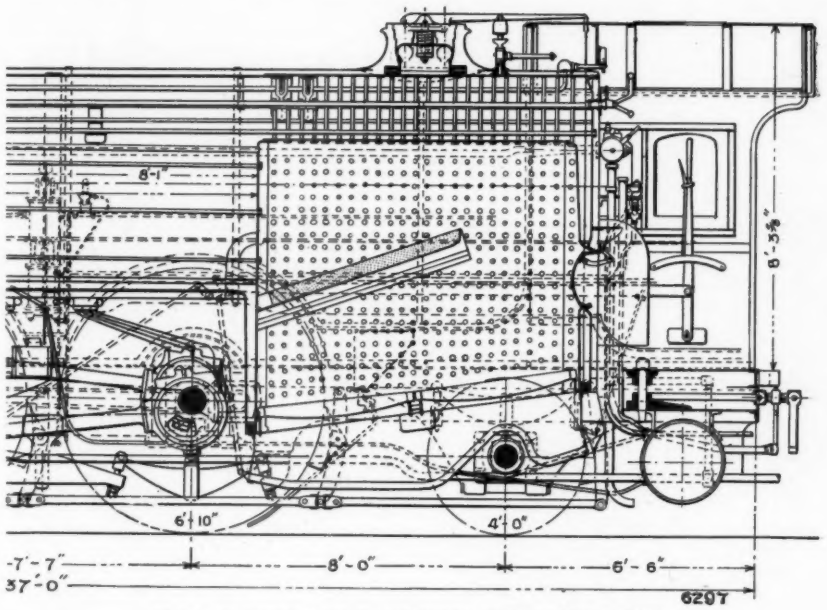
The bearing springs are to be made of seven plates of 4-in. by $\frac{3}{8}$-in. steel; to have $6\frac{1}{2}$ ins. of camber unweighted, and a wrought-iron buckle 3 ins. by $\frac{1}{2}$ in.; the plates to be secured in the buckle with a $\frac{1}{2}$-in. mild steel rivet in the middle.

They must be made of approved material and be tested at the maker's works by an inspector, strictly in accordance with the specification in clause 19 of the appendix to the specification, which reads as follows :—

The bearing springs must be of the best workmanship and well tempered; the inspector will examine the springs as manufactured, and will reject any he may consider defective in material or workmanship, or that do not stand the following tests :—

(*a*) Each bearing spring to be brought back under the scrag quite straight, and then to resume its original camber; the back plate, when detached from the rest of the plates after scragging, to stand up to its original camber.

(*b*) Each buffing spring to be brought back under the scrag quite straight, and then to



DETAILS OF 4-4-2-TYPE EXPRESS LOCOMOTIVE, NORTH-EASTERN RAILWAY.

resume its original camber; the back plate, when detached from the rest of the plates after scragging, to stand up to 12 ins. camber.

(*c*) Each pin to be scragged without the buckle, and the inspector to be allowed an opportunity of examining the parts before the buckle is put on.

The drawings are self-explanatory, and the specification contains no further reference to them beyond the clauses relating to the tests which are to be applied to determine the ultimate tensile strength of the materials employed. These clauses were set forth in detail in the December Notes in FEILDEN'S MAGAZINE.

Steam Passenger Coach for the Taff Vale Railway.

THE writer is indebted to Mr. T. Hurry Riches, Locomotive Superintendent of the Taff Vale Railway, for the accompanying photograph of the new steam passenger car which he has designed for service between Cardiff, Penarth, and Cadoxton, a distance of 9 mls. 39 chns., involving gradients of considerable length at 1 in 40.

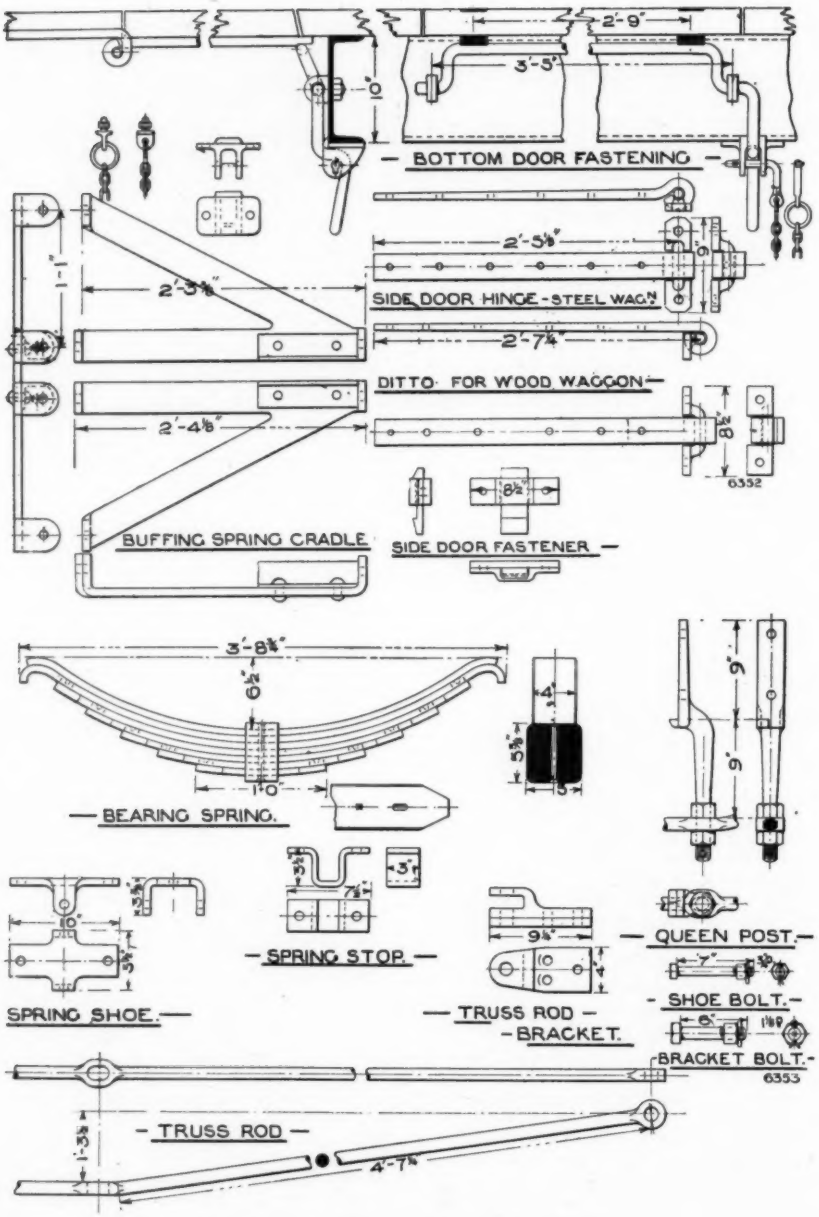
The seating capacity is for twelve first class and forty third-class passengers, and a luggage compartment is also provided.

The third-class compartment is arranged with transverse seats and a central gangway. The first-class portion has longitudinal seats upholstered with figure velvet plush, and the roof is lined with lincrusta Walton, both compartments being steam-heated on Messrs. G. D. Peter's system. The car under-frame is of steel and is carried at one end on an ordinary carriage bogie, the other end being supported by the engine bogie.

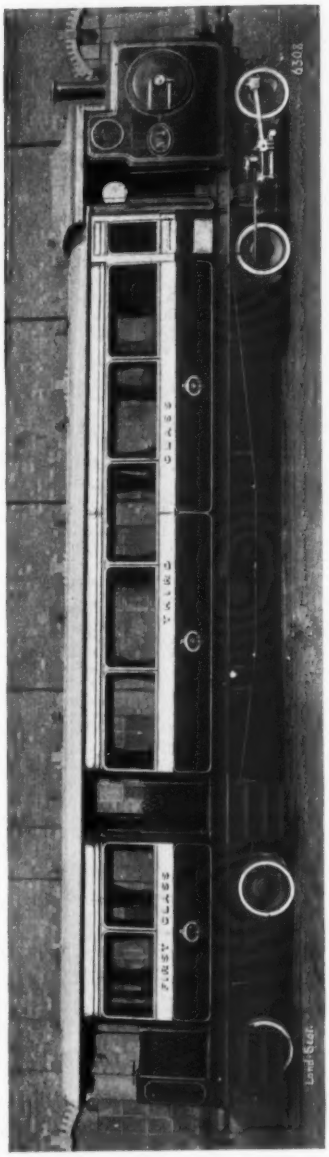
The total length of the car over buffers is 58 ft. 9 ins., distance between centres of bogies 40 ft. 9½ ins., and total wheel-base 49 ft. 3½ ins. The total weight is 33 tons 2 cwts.

The boiler is of the multitubular type, constructed of steel plates, with a copper firebox. The tubes are 1¾ in. in diameter and 312 in number. The cylinders are fixed between the wheels on the outside of the frame, and the connecting-rods drive the end pair of wheels. Contrary to the practice on the South-Western and Great Western railways, the valve gear is Stephenson's link type, and not of the Walschaert pattern as in the other cases mentioned. Steam and hand brakes are provided.

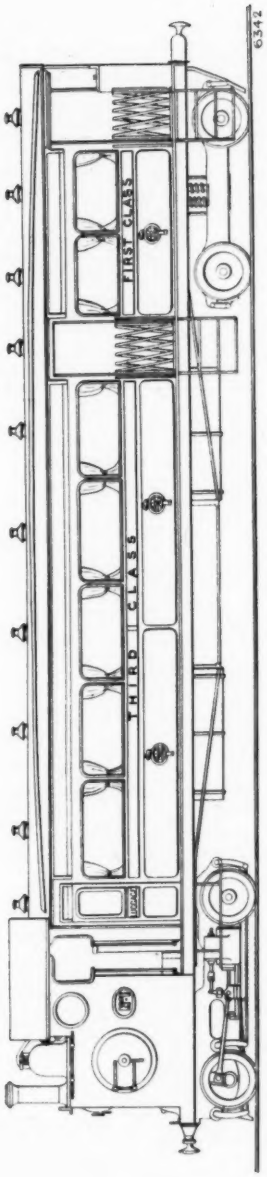
The dimensions of the engine are as follows:—



PRIVATE OWNERS' 20-TON WAGON.—IRONWORK DETAILS.



TAFF VALE RAILWAY STEAM CAR: GENERAL VIEW



TAFF VALE RAILWAY STEAM CAR: SIDE ELEVATION.

Boiler, heating surface (tubes) ...	...	299·5 sq. ft.
,, Firebox ,, ...	...	39 ,,
	Total	338·5 sq. ft.
Grate area	...	8 sq. ft.
Boiler, working pressure .	...	160 lbs. per sq. in.
Cylinders	... diam.	9 ins.
,, ...	stroke.	14 ins.
Engine ... ... wheelbase	...	8 ft. 6 ins.
,, ... ,,	diam.	2 ft. 10 ins.

The water capacity of the tanks is 530 gals., and the coal bunker will accommodate 10 cwt. of coal. The tractive power taken at 80 per cent. of the working pressure is 4·263 lbs. Mr. Hurry Riches has kindly provided the writer with full working drawings of this car. The reproduction of these drawings will commence with next month's notes.

Locomotive "Experiments" on the L. & N.W. and L. & S.W. Railways.

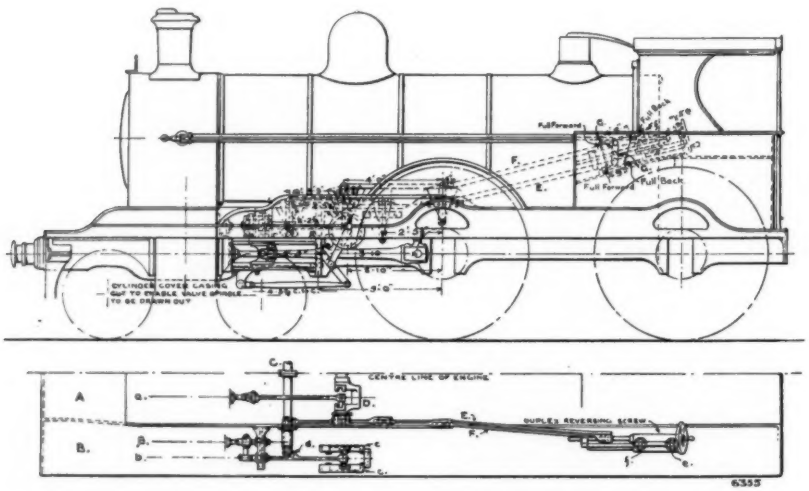
THE locomotive superintendents of the above railways are each endeavouring to increase the efficiency of existing engines by providing them with additional mechanism.

On the London and North-Western Mr. Whale has fitted some of the Webb four-cylinder compound express locomotives of the "Alfred the Great" class with a type of duplex valve gear, by the aid of which the point of cut-off may be varied independently in each cylinder.

As originally constructed, these engines were fitted with an arrangement whereby the four valves were actuated by only two sets of valve gear,* and Mr. Webb considered that the saving thus effected in first cost and subsequent maintenance more than counterbalanced any advantage which might be urged on behalf of variable expansion in each pair of cylinders. There is nothing new about Mr. Whale's gear. It is—as he himself says—simply an adaptation of the Joy motion to suit the conditions which it is desired to introduce. There is only one reversing screw, which actuates both the high- and low-pressure reversing shafts either together, or independently of one another. A short beam is provided, which is pivoted on a central pin connecting it to the main screw operated by the hand wheel in the cab.

The high- and low-pressure reversing-rods

Feilden's Magazine, November, 1902, pp. 421, 424, 425.



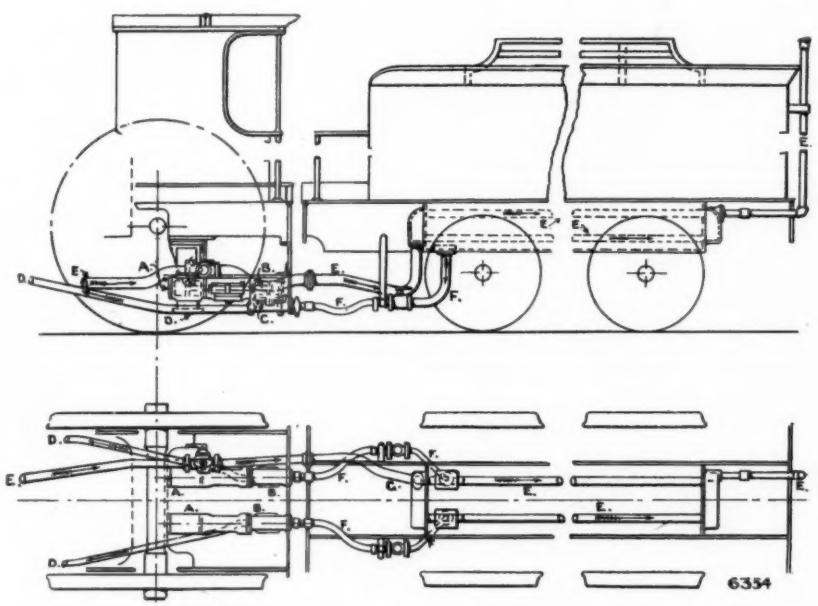
DUPLEX VALVE GEAR, LONDON AND NORTH-WESTERN RAILWAY.

A Position of low-pressure cylinder.
a Centre line of low-pressure cylinder and steam chest.
B Portion of high-pressure cylinder.
b Centre line ,, ,,
β ,, ,, steam chest.
C High-pressure reversing shaft.
c ,, ,, discs.
D Low-pressure reversing shaft.
d Connecting link between reversing shaft and discs.
E High-pressure reversing rod.
e Hand wheel and screw for locking high-pressure reversing rod.
F Low-pressure reversing rod.
Hand wheel and screw for locking low-pressure reversing rod
G Mid gear.

are coupled to the beam, to each end of which is attached a short rod, which slides in a recess in the bracket casting, and this rod can be locked in any position by means of a small hand wheel and screw; so that after the engine has started with both high- and low-pressure reversing shafts in full forward gear, the end of the short beam, which carries the low-pressure rod, can be locked in that position by means of the small hand wheel and screw; and by revolving the large hand wheel and screw the other end of the beam with the high-pressure rod attached can be moved back, and the travel of the high-pressure valve thereby varied, whilst the low-pressure valve is working at full travel. Studs fixed in the locking bars engage in slots in the bracket casting, and by this means the maximum angle required for each reversing shaft is determined. The few engines which have so far been fitted with this gear are said to be giving improved results both with regard to loads hauled and economy in fuel consumption. Quite recently engine No. 1958, "Royal Oak," was seen on several successive occasions working the 2 p.m. corridor express out of Euston, assisted by a pilot, the load being 19½ coaches. There is nothing in this, of course, to demonstrate that the engines have not in reality been improved by the alterations which have been carried out upon them, but in view of the utterances of certain writers and others who asserted that the new gear was to do away once and for all with piloting on the London and North-Western with loads up to 20½ coaches the fact is to be noted. The absurd 17-coach limit was no doubt responsible for the presence of the pilot engine on the occasions referred to, but in any case this was quite as superfluous before as since the improved gear made its appearance.

On the London and South-Western Railway Mr. Drummond has introduced a feed-water heating device. This has been applied to engine No. 720, the first of the four-cylinder simple express engines built at Nine Elms in 1898.

The exhaust steam from the pumps which



LOCOMOTIVE FEED-WATER HEATER, LONDON AND SOUTH-WESTERN RAILWAY.

A Steam cylinder (5½ ins. diam. 9 ins. stroke).
B Pump (4½ ins. diam. 9 ins. stroke).
C Valve box.
D Delivery from pump.
E Exhaust steam from cylinder.
F Pump Suction.
G Exhaust steam from pump.

deliver the hot feed-water to the boiler is sent to the tender with that portion of the main exhaust utilised for the purpose. The water is pumped into the boiler at a temperature of about 180 degs. Fahr.

Mr. Drummond states that a saving in fuel equal to 6 lbs. per mile has been effected during the time that the engine has been running fitted with the device. The tank from which the feed is immediately drawn, and through which the exhaust steam heating pipes are led, is supplementary to the tender tank. The water condensed escapes through a series of holes in the rear casting receiving the ends of the pipes, whilst the steam not condensed passes into the atmosphere through an escape pipe at the rear of the tender. This arrangement is shown in the accompanying drawing. The exhaust steam, which is more or less charged with grease, has no contact whatever with the water in the tender, and thus a frequent cause of overheating firebox plates is avoided.

CATALOGUES RECEIVED.

Consolidated Pneumatic Tool Co., Ltd., Palace Chambers, 9, Bridge Street, Westminster.—A handsome and well-illustrated catalogue for 1904 of this firm's specialities, including the Boyer hammer, gap-riveter, jam-riveter, Little Giant drill, improved reversible and Boyer drills, rivet-heating forges, pneumatic geared wire-rope hoist, etc. The latter part of the book is devoted to illustrations of the tools in actual use.

Thomas Matthews, Artesian Well Borer, Imperial Iron Works, Pendleton, Manchester.—Tools and pumps relating to the obtaining of water supplies.

J. Parkinson & Son, Canal Iron Works, Shipley.—Two leaflets calling attention to the necessity for efficient equipment, more especially with reference to tools, of which one, "A Slogging or High-speed Lathe," is illustrated.

Rimmington Bros., Carlisle.—Booklet dealing with the Manzel's automatic locomotive lubricating system. Compressed air is used in operating this system, and the amount of oil supplied is governed by the steam consumption, and varies according as the engine works under full pressure, or by velocity or coasting down an incline.

Moorhouse Sidney & Co., Victoria Brass and Iron Works, Stalybridge.—Sectional catalogue of high-class engine and boiler-mountings.

Joseph Green & Nephew, Globe Iron Works, Hunslet, Leeds.—Wood-working machinery and accessories.

Bridge, David & Co., Castleton Iron Works, Castleton, Manchester.—Improved ice-crushing machinery and other appliances of interest to ice manufacturers, ice merchants, etc.

Sharples, Wm. & Co., Ltd., Irwell Foundry, Ramsbottom, nr. Manchester.—Machine-moulded wheels for high-speed gearing, double-cylinder barring-engine, with automatic releasing-gear.

Stevensons, Ltd., Canal Foundry, Preston.—A well-illustrated catalogue of steel and iron casting ladles, which range in capacity from 3 up to 60 tons capacity.

Harrison Bros., Atlas Foundry, Lower Commercial St., Middlesbro'.—Pamphlet dealing with Harrison's Patent Diamond Grit, a substitute for sand in the operations of sawing and rubbing granite, marble, freestone, etc.

Andrews, J. E. H. & Co., Ltd., Reddish, Stockport.—A booklet entirely devoted to the illustration and description of the "Stockport" gas-engines of various types, from 1½ to 150 h.-p.

Thorn & Hoddle Acetylene Co., Ltd., 151, Victoria St., S.W.—List of fittings, etc., for the installation of acetylene lighting, with special description of the "Incanto" generator, a patent of this firm.

Seaham Harbour Engine Works, nr. Sunderland.—Catalogue (Section A) dealing with the Londonderry steam wagon, and giving the results of efficiency tests carried out.

Ley's Malleable Castings Co., Ltd., Derby.—A handsome and interesting catalogue dealing with and illustrating the "Blackheart" malleable castings and process of manufacture.

C. W. Hunt Company, West New Brighton, N.Y.—Narrow-gauge railway plant sold under the trade name of "Industrial."

Wood, John & Edward, Victoria Foundry, Bolton. Corliss engines—mill gearing—accessories—superheaters.

Rice & Co. (Leeds), Ltd., Leeds.—A handsomely bound book containing illustrated descriptions in three languages of all kinds of hydraulic machinery.

Ward, Haggas & Smith, Eastwood Tool Works, Keighley.—Lathes, planers, drilling and boring machines, shaping machines.

Hornsby, Richard & Sons, Ltd., Grantham.—Booklet dealing with the Hornsby "Upright" water-tube boiler.

Pethick Bros., Laira Bridge, Plymouth, have issued a pamphlet entitled "Enough Granite to Build Ten Londons," being a description of their quarries at Princetown, S. Devon, and also of various well-known structures built of Devonshire granite from Pethick's quarries.

NEW MACHINERY & APPLIANCES

New Upright Water-Tube Boiler.

SOME months ago a new type of water-tube boiler for land service was introduced by Messrs. Hornsby and Sons, Ltd., of Grantham.

It is of the straight tube type, and in construction is of the simplest character, consisting essentially of a water and steam drum with bundles or nests of tubes, each set being provided with its separate headers, and the whole connected together by expanded nipples both in the steam and water spaces. One of the features of this steam raiser is that the back nests of tubes are arranged vertically, and receive the feed water, thus acting as economisers. They also serve to liberate some of the impurities of the feed water, which are deposited in the bottom back headers.

The accompanying illustration will serve to convey a good idea of the arrangement of the parts, and it will be noticed that the tubes are easily and completely accessible.

The most interesting characteristic of the boiler, however, has been brought to light as a result of a trial extending over eighteen months, and which was conducted by independent experts with a view to obtaining accurate information as to the condition of the boiler in general, and especially as regards deposits and incrustations in the tubes and headers.

It consists in the fact that the steam generating tubes, viz., the front rows, were found to be practically self-cleaning.

From considerations of both safety and efficiency, this development is of the utmost importance, especially as regards water-tube boilers, as the chief objection most frequently raised against this type is—especially in cases where the feed water is bad—the great loss of efficiency due to scale formation and the difficulty of its removal.

The boiler tested was first put under steam in June, 1902, and has been working regularly since then at 150 lbs. pressure, as one of a battery of five water-tube boilers supplying steam to the engines driving a portion of Messrs. Hornsby's works. The other four were of a different type, in which the tubes were inclined horizontally.

The boiler was made up as shown in the illustration, and was provided with 14 sections, each containing 19 tubes, with top and bottom headers.

The steam generating tubes were, however, arranged in three rows and staggered, the first row being inclined over the grate; the economiser and feed-tubes were arranged vertically at the back.

The total evaporation was between 10,000 and 15,000 lbs. of water per hour. On analysis the water used was shown to contain 23·14 grains of solids per gal., and to possess a total hardness of 21·9 degs. The latter was divided as follows, viz., 14·6 degs. temporary hardness and 7·3 degs. permanent hardness.

The result of the inspections uniformly demonstrated that the mud, consisting of about 95 per cent. of carbonates, was almost entirely deposited in the back economiser sections, where the feed is. A small quantity was found in the top-headers, about $\frac{1}{4}$ in. thick in the tubes for a distance of about 2 ft. down, the lower parts of the economiser tubes being practically clean, the bulk of the mud being found in the mud-drums. The mud in the tubes and headers was in the form of a soft deposit, and was easily removed by the brush, without using the scraper; that which settled in the bottom drums was at intervals blown out by opening the blow-off cocks.

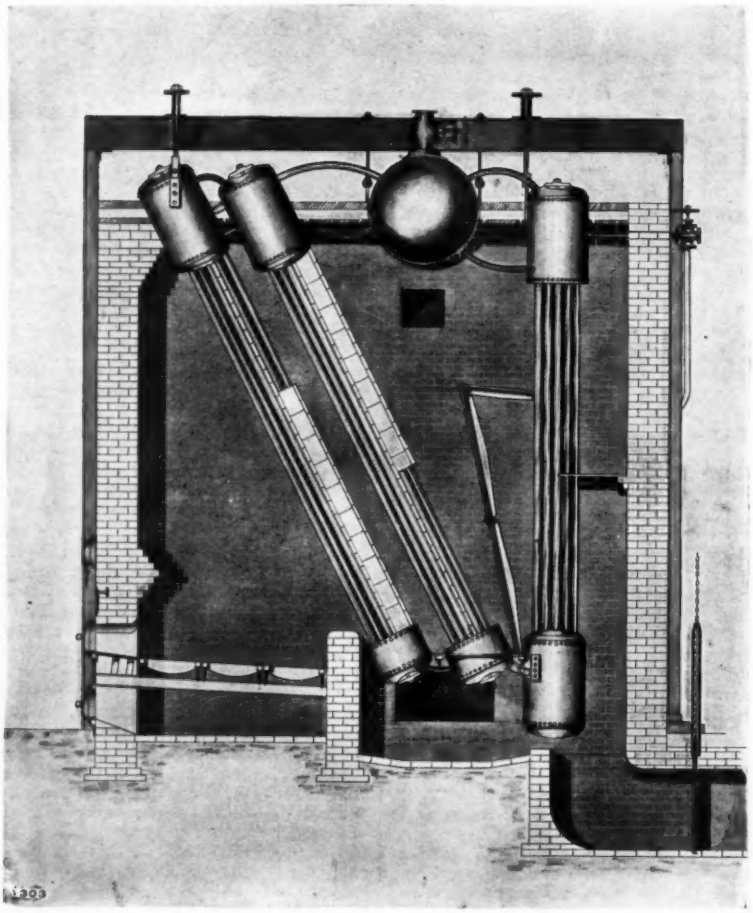
Thin scale was formed in the tubes of the front sections which, however, was found chiefly in the bottom headers broken up in small pieces. The small portion adhering to the tubes was found in the lower portions only, and was readily detached by an ordinary brush—the scraper not being necessary.

In the front headers, this scale ranged between $\frac{1}{64}$ in. to $\frac{1}{32}$ in. in thickness; that in the second row was less thick and softer, and that in the third less thick and softer still.

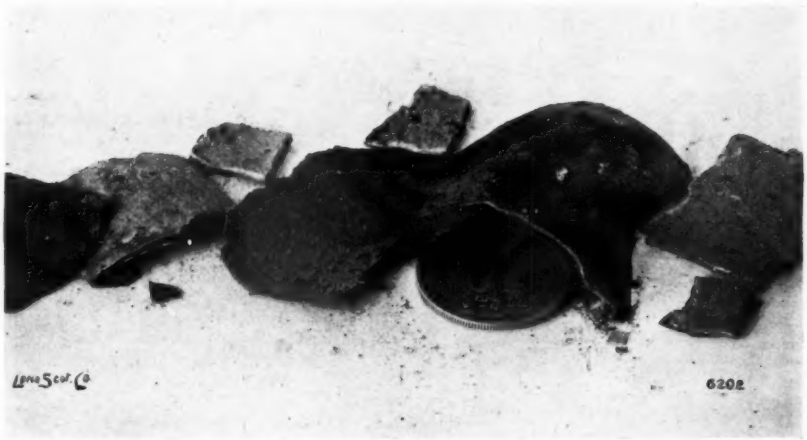
The deposit in the steam drum consisted of a coating of soft scale and mud, not more than $\frac{1}{32}$ in. thick, extending up to the water line, and the nipples—connecting the top and bottom headers—were clean, excepting for a very slight coating of soft mud found in those leading from the economiser sections.

The accompanying illustrations are from photographs of the scale as it was taken out of the bottom headers, and are reproduced, showing the shape, and, relatively to a coin, the size and thickness of the fragments that fell to the bottom.

A front tube, $3\frac{1}{4}$ ins. diameter and $\frac{1}{8}$ in. thick, which had been in use for 18 months, was also taken out from the front row and cut into sections, to ascertain and show its condition. A reproduction from a photograph of one of these sections cut longitudinally in half is also shown, in which may be seen portions of the scale adhering to the bottom half of the tube, and the edges where the rest of the scale has cracked off and dropped away. The upper half will be observed to be quite clean. The scale still adhering is barely $\frac{1}{16}$ in. at the thickest part, and tapers off to nothing.



MESSRS. HORNSBY'S STANDARD UPRIGHT WATER-TUBE BOILER.



PIECES OF SCALE FOUND IN BOTTOM FRONT HEADER.

It is, of course, due to the unequal expansion and contraction of the scale and that of the tubes that the former becomes detached, and the nearly vertical position of the tubes allows the scale to fall down to the bottom header, the size of which has been arranged to allow a considerable quantity to accumulate without in any way interfering with the circulation of the water.

The cleaning operation, which was performed every six weeks, is very simple, and is performed by an ordinary tube brush without emptying the boiler, the pressure being let down and covers taken off.

The time taken to clean all the tubes from the commencement of the fall in pressure to steam at full pressure again was about four hours.

We are informed by the works manager that the boiler is steaming as well to-day as when first put under steam. The firebrick baffles, including those on the front tubes and immediately over the fire, which are subject to the greatest heat, are in perfect condition.

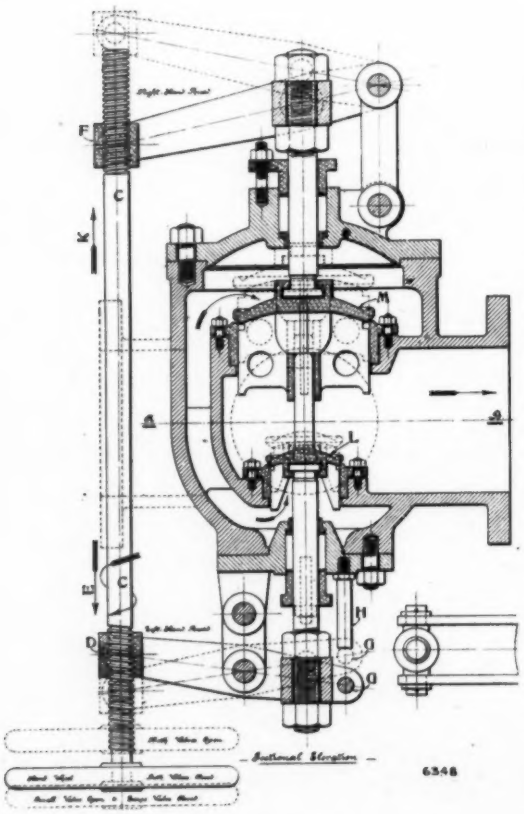
FRONT TUBE CUT THROUGH SHOWING SCALE IN BOTTOM HALF, THE UPPER HALF BEING QUITE CLEAN.

Green's Patent Valve.

THE principal defect of the double-beat or equilibrium valve, when used for high-pressure steam, has been shown by experience to consist in the unequal expansion of the metal forming the body of the valve and the metal composing the valves and spindles.

Although the valves may have been accurately ground into their seats and the greatest care employed in fitting them, it has nevertheless been found that, under working conditions, the high temperature of the steam so affects the expansion of these delicately fitted parts, as to render it difficult to keep them steam-tight. The valve illustrated herewith has been designed with the object of overcoming these difficulties, and at the same time ensuring easy operation and control.

Referring to the illustration, it will be seen that the method employed is extremely simple, and that no pilot valves or other small intricate parts are embodied in the design. The valve is so arranged that the smaller valve *L* has the pressure on the underside, and the larger valve *M* the pressure on the top; by this arrangement the smaller valve will open first when the operating gear is put in motion, the opening movement continuing until the pressure is equal on both sides of the larger valve. The extent of the lift on the smaller valve is controlled by a stop on the cover. On this stop coming into operation, the larger valve, which in the meantime has become balanced, commences to open.



DETAILS OF GREEN'S VALVE.

To make this quite clear we will examine the method of operation in detail. Assuming that both the valves are closed, by revolving the hand-wheel with a left-hand motion, the spindle *C* is thereby revolved and the lower nut *D*, having a left-hand thread, travels downwards. At the same time the operating spindle travels downwards, in the direction of its length, through the top nut *F*, which is screwed with a right-hand thread, and is held stationary owing to the pressure being on the upper surface of the larger valve *M*. The downward movement of the spindle and lower nut *D* causes the smaller valve *L* to open, the action continuing until the pin at end of lower lever comes in contact with the stop on the bottom cover. The pressure is now equal on both sides of the larger valve. By still further revolving the hand-wheel the operating spindle will now travel longitudinally in an upward direction, as the lower nut is now stationary and unable to travel further, owing to the stop. At the same time the nut *F* will also travel upwards along the spindle, this action opening the larger valve.

When closing the valves, the motion of the hand-wheel is reversed, the larger valve having the steam pressure on the top side will close first.

It will be noticed that the distance between the valve faces is not a fixed dimension, and that

the independent action of the two valves permits of automatic adjustment to suit the distance between the seats. This feature is, in fact, one of the chief advantages of the valve, as it is claimed that the trouble usually experienced with the ordinary equilibrium valve is thereby eliminated.

The ability to operate one valve independently is another great advantage, as it is frequently necessary to pass only small quantities of steam: for example, when "warming through" engines before starting and in the case of marine engines when it is required to run at low speed, or going in and out of port, when a valve which can be easily and quickly operated is of very great convenience and value.

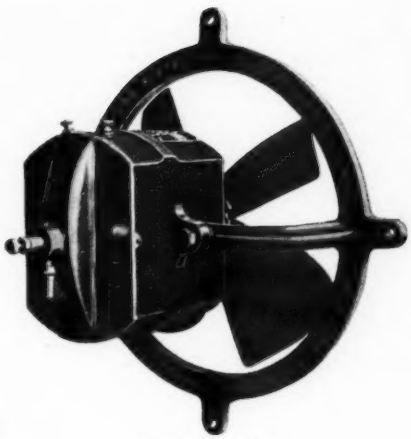
The makers are Messrs. Holden & Brooke, of West Gorton, Manchester.

A New Motor-Fan.

ARCHITECTS and others who are called upon to provide arrangements for the ventilation of small apartments, ship state-rooms, lavatories, etc., will appreciate some information concerning a very efficient form of motor-fan recently brought out for this purpose by Messrs. John Gibbs & Sons, Duke Street, Liverpool.

These machines, the blades of which are 12 ins. diameter, are of first-class workmanship throughout, and very different to the cheap American and German machines which at present flood the British market. The motor, which is as small as possible consistent with ability to work a fan of this size without undue over-heating, is constructed throughout of laminated sheet-iron plates carefully insulated. The magnets are of the enclosed double-circuit type, and the pole tips of such a section as to do away with the magnetic hum so common in small machines of this class. The armature is of the slotted type, carefully wound and provided with mica insulation. The commutators are of ample section, and are sufficiently deep to permit of turning up several times. The brush-holders, a part of some small machines which is a continual source of trouble, are designed to require a minimum amount of attention. They are fitted with square carbon brushes, and are insulated from the cast brass brush-rocker by ebonite and mica.

The bearings are brass bushed, and are fitted with steel balls, so that the thrust caused by the propeller-like action of the fan blades is taken up with a minimum amount of friction. Solid grease lubricators are fitted on the fans also with a view to lessening the attention required.



A NEW MOTOR-FAN.

The whole motor is entirely enclosed in a cast metal case of either cast iron, brass, or aluminium, and which can be electro-plated if required. This casing protects the motor from all injury, dust, etc., and is practically watertight, whilst the back is instantly removable, if required, for renewing brushes, etc.

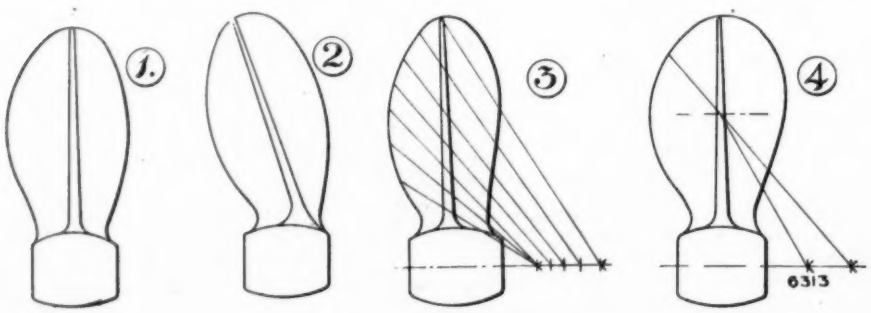
The propeller itself—which, after all, is the most important part of the machine—is of special design. The blades are of the open type, similar in form to the larger sizes which Messrs. John Gibbs & Sons have found by careful experiment to be the best one for propelling air with a maximum efficiency and a minimum of power. They are built into a patent form of interlocking fan-boss which consists of two halves of cast metal screwed together with set screws, and interlocked with flanges so as to prevent the possibility of the blades flying out even at very excessive speeds.

Reference to the illustration shows that the fan and motor can be very easily transferred to another ring and fitted elsewhere. This is effected by means of two bolts with wing nuts, and is especially useful when these machines are for use on board ship, where, owing to the small power consumed, they can be worked with an adaptable plug off the lamp connection and moved about as required.

WORKSHOP PRACTICE.

Machining Propeller Blades.

As evidence of the importance attached to the details of marine engineering, we note that quite a departure has been made from the ordinary in machining the working faces of propeller blades. Hitherto, the helical face of the blade has been formed by sweeping up a loam mould, from which a cast-iron pattern is made. This, in turn, is afterwards moulded in green or dry sand, and the working castings made in either steel or some alloy, as aluminium or phosphor-bronze. To those of our readers who are familiar with the form of a propeller blade, we submit that the unequal distribution of the metal—unavoidable, of course—consequent upon the varying sections of the blade from neck to tip, has a decided tendency to produce distortion. This means departure from the original lines of the mould, representing either a true helix, or a blade surface of varying pitch. This we believe to be the real cause of the variations which were discovered in the propeller blades of the North German liner, *Kaiser Wilhelm II.* This discovery suggested the making of a machine that would be capable of producing a true helical surface for the entire length of the blade, or graduated as desired. In the case mentioned, a careful examination was made of the working surface of the blade. Measurements were taken in a longitudinal direction at distances of 2 ft. apart. The extreme points at one of these divisions, showed a discrepancy of half-an-inch in each direction from the correct angle, thus making a total of 1 in. in 2 ft. This would at once destroy all the results anticipated by a designer, who had based his calculations on a screw having perfectly theoretical lines, and with the several allowances made for slip, etc. To eliminate these differences a machine has been designed and built by Dr. G. Bauer, the chief engineer of the Stettiner Machine Co., Germany. This has been in operation on the propeller blades of both the *Kronprinz Wilhelm* and the *Kaiser Wilhelm II.* of the North German Lloyd. The machine, which is very massive, weighing with the necessary equipment about 40 tons and standing over 16 ft. in height, is capable of dealing with propellers up to 23 ft. in diameter. The mechanism, which is most ingenious, is somewhat complicated, owing to the variations of the several pitches with which it is intended to deal. Some idea of its scope may be gathered from the area of



MACHINING PROPELLER BLADES.

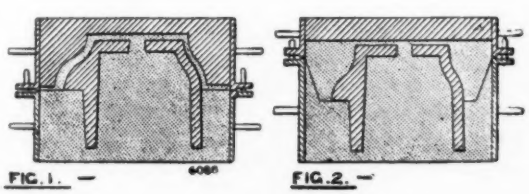
one of the blades, which represents nearly 37 sq. ft. of machined face. This large surface occupied 150 hrs. in machining, one operator only being engaged on the work. Although there is always considerable variation between the angle at the tip and the angle at the root of the blade, it was found quite unnecessary to change the tool. The entire blade surface may therefore—under normal conditions—be machined without alteration provided a suitable cutting angle is adopted. The tool is mounted on a sliding ram, but, as in an ordinary planing or shaping machine, the tool-box is hinged to enable the tool to trail over the surface on the return stroke. The arm of the machine — which somewhat resembles a large radial drill—moves round a central pillar, fixed in a base provided with faces to which the boss-end of the blade is bolted. These faces are arranged with radial slots, which allow of the blade being moved round to suit a varying pitch, or permit any alteration found desirable. By a series of concentric helical cuts, a correct helical surface is obtained, the generating line of which may be at right angles to the axis, or inclined to the same, or may be broken, as in the case of blades having pitches increasing both radially and longitudinally, as at Figs. 1, 2, 3, 4. This is attained by the combined vertical and rotary movements of the machine arm, whilst special gearing operates the spindles for imparting the necessary radial and axial feeds. Whilst admitting the necessity of having the working face of the blade theoretically correct, it will be interesting to know if the removal of the skin of the metal by the operation does not materially help to shorten the life of the blade by exposing a weakened surface and one more susceptible to wear.

Milling Cutters.

The almost illimitable operations which can now be performed on the modern milling machine demand the use, at times, of very expensive cutters. The smaller sizes up to six or eight inches diameter have been made out of good tool-steel which costs anything from a shilling per pound upwards in the raw material. This is an important item when we consider that the cost of the cutter blank is enormously increased by the several operations through which it passes before becoming a useable accessory. The different stages include the annealing, turning up to correct form, cutting the spaces to form the teeth, backing-off the latter, and then the hardening—an operation frequently attended with anything but satisfactory results—and finally, the internal grinding of the hole and the sharpening. The utilising of apparently waste material is something which will appeal to most works-managers, especially when good results can be cheaply obtained. The making of the larger sizes of milling cutters offers an opportunity for dealing with such pieces as the slabs of metal which are usually sawn out of the solid forging during the operation of making a solid crank. In modern practice, mild steel is invariably used, and the forging renders the material particularly suitable for the purpose. On a recent visit to a large engineering shop in the north, we noticed several cutters which were being used for milling the jaws of the cranks. These were pointed out by the manager as having formed part of the forging upon which it was then operating. The whole of the pieces thus removed from the forgings—instead of being relegated to the scrap-heap — were bored and turned up, spirally grooved, and afterwards case-hardened on the teeth only. We were informed that excellent results were obtained with an entire absence of risk which had been frequently met with when using high-grade tool steel.

Moulding Boxes.

As a proof of the saving which may be effected by the use of proper moulding boxes, we have only to refer to Figs. 1 and 2 in the illustration. In many shops great neglect is shown towards the foundry in the matter of equipment, and many managers treat this section of the works in rather a scant manner, looking upon the foundry as a place to supply castings without considering the inconvenience under which at times the moulders work. In the works the fitting up of moulding boxes is nearly always looked upon as a bugbear which seriously interferes with the legitimate work of the shop. A considerable sum was lost in the making



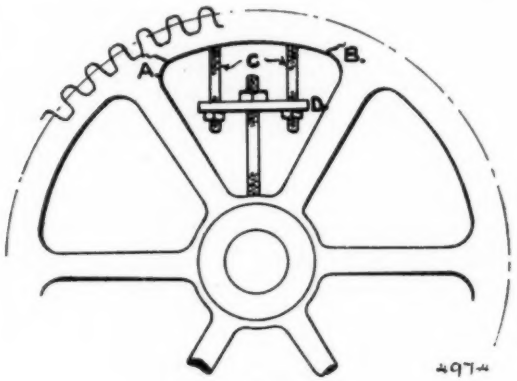
MOULDING BOXES.

of a quantity of castings of channel sections, as shown in the illustration, Figs. 1 and 2, owing to the objection on the part of the manager to have a new box made, thinking at the time that he was cutting down expenses. After some argument the request was granted, the work still proceeding with the arrangement shown at Fig. 2, where, in addition to the making of a "drop" joint, a barrowful of "gaggers" were employed to support the sand in each mould. With the advent of the box (Fig. 1), where the bars follow the contour of the pattern, a saving of 80 to 100 per cent. was made, and an entire absence of "scabbed" castings. J. A. P.

Repairing Broken Gear.

The illustration shows a repair to a gear wheel broken at the rim as shown at *A* and *B*. Two studs screwed at each end were inserted in the rim and secured to the underside of an ½-in. wrought iron plate *D* with a couple of nuts. A central stud was then screwed into the boss of the wheel and passed through the plate *D*. The broken segment was then fixed in position and held fast by a nut on the central stud tightened against the plate.

J. B.



REPAIRING BROKEN GEAR.

ENGINEERING ABSTRACTS

LIST OF PUBLICATIONS REGULARLY REVIEWED.

Amer. Engin. & Rlrd. Jnl.	American Engineer and Railroad Journal	New York	2/-
Amer. Machst.	American Machinist	New York	-/8
Amer. Machy.	American Machinery	New York	1/4
Ann. Ing. Gand	Annales de l'Association des Ingénieurs de Gand	Brussels	3/-
Aut. Jnl.	Automotor Journal	London	-/6
Brit. Archt.	The British Architect	London	-/8
Brit. Claywkr.	The British Clayworker	London	1/-
Builder	The Builder	London	-/6
Bldrs.' Jnl.	Builders' Journal and Architectural Record	London	-/4
Bldng. News	Building News	London	-/8
Canad. Mfr.	Canadian Manufacturer	Toronto	1/3
Coll. Gdn.	The Colliery Guardian	London	-/7
Compte Rendu Soc. Ing. Civ.	Compte Rendu des Travaux de la Societe des Ingénieurs Civils de France	Paris	3/6
Der Mechr.	Der Mechaniker	Berlin	1/-
Ding. Poly. Jnl.	Dingler's Polytechnic Journal	Berlin	3 mos. 7/6
Echo des Mines et Métall.	L'Echo des Mines et de la Metallurgie	Paris	f.45.00 p.a.
Écl. Élec.	ÉclairageÉlectrique	Paris	1/8
Elec. Eng.	The Electrical Engineer	London	-/4
Elec. Rev.	Electrical Review	London	-/7
Elec. Rev., N.Y.	The Electrical Review, N.Y.	New York	1/-
Elec. Times	Electrical Times	London	-/3
Elec. Wld.	Electrical World & Engineer	New York	1/4
Electrician	The Electrician	London	-/7
Électricien	L'Électricien	Paris	1/4
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Electricity	Electricity	New York	1/4
Electro-Chemist	Electro-Chemist & Metallurgist	London	3/-
Elec. Techr.	Der Electro-Techniker	Vienna	1/-
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Elektrotek. Tidsft.	Elektroteknisk Tidsskrift	Christiania	1/4
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Elettricista	L'Elettricista	Rome	1/4
Elettricita	L'Elettricita	Milan	1/-
Energ. Electrica	La Energia Electrica	Madrid	1/4
Engineer	The Engineer	London	-/7
Engineering	Engineering	London	-/7
Eng. and Min. Jnl.	The Engineering & Mining Journal	New York	1/4
Eng. Mag.	The Engineering Magazine	New York & London	1/4
Eng. News	The Engineering News	New York	1/4
Eng. Rec.	The Engineering Record	New York	1/4
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Ice and Cold Storage	Ice & Cold Storage	London	1/-
Ind. Elec.	L'Industrie Électrique	Paris	2/-
Iron Age	Iron Age		
Iron and Coal Trades' Rev.	Iron and Coal Trades' Review	London	-/7
Iron and Steel Metallst.	Iron and Steel Metallurgist	Boston, Mass.	3/6
Iron Trade Rev.	Iron Trade Review	Ohio	17/6 p.a.
Iron and Steel Trades' Jnl.	Iron and Steel Trades' Journal	London	-/6
Jnl. Am. Soc. Naval Engr.	Journal American Society of Naval Engineers	Washington	25/- p.a.
Jnl. Assoc. Eng. Soc.	Journal of the Association of Engineering Societies	Philadelphia, U.S.A.	2/-
Jnl. Chem. & Metall. Socy.	Journal of the Chemical Metallurgical and Mining society	Johannesburg	2/8
Jnl. Gas Lighting	The Journal of Gas Lighting	London	-/7
Jnl. Franklin Inst.	Journal of the Franklin Institute	Philadelphia, U.S.A.	2/-

Jnl. I. E. E.	Journal of the Institution of Electrical Engineers	London	Varies from 1/6 to 7/6
Jnl. Iron & Steel Inst.	Journal of the Iron and Steel Institute	London	16/– per vol. (two annually)
Jnl. San. Inst.	Journal of the Sanitary Institute	London	...
Jnl. Soc. Arts	Journal of the Society of Arts	London	–/7
Jnl. Western Soc. Enr.	Journal of the Western Society of Engineers	Chicago, U.S.A.	3/–
Knowledge	Knowledge	London	–/7
La Mach.	La Machine	Geneva	3/– 6 mos.
Light Rly. & Tram. Jnl.	Light Railway and Tramway Journal	London	1/1
Machinery	Machinery	New York	2/–
Marine Engr.	Marine Engineer	London	1/1
Marine Engg.	Marine Engineering	New York	2/–
Mech. Wld.	Mechanical World	Manchester	–/3
Métallurgie	La Métallurgie	Paris	20/– p.a.
Mines and Minerals	Mines and Minerals	Scranton, Pa.	2/–
Mit. Verein. Strassenbahn.	Mittheilungen des Vereines für die Förderung des Local- und Strassenbahnwesens	Vienna	...
Mod. Machy.	Modern Machinery	Chicago	1/4
Nat. Ldry. Jnl.	National Laundry Journal	Chicago	1/4
Nature	Nature	London	–/7
Power	Power	New York	2/–
Pract. Eng.	Practical Engineer	.....	–/6
Proc. Am. Soc. C.E.	Proceedings of the American Society Civil Engineers	New York	Mbrs. only
Proc. Can. Soc. C.E.	Proceedings of the Canadian Society of Civil Engineers	.....	Mbrs. only
Proc. Engs. Soc. W. Pennsya.	Proceedings of the Engineers Society of Western Pennsylvania	Pittsburg	3/–
Proc. Inst. C. E.	Proceedings of the Institution of Civil Engineers	London	Mbrs. only
Proc. I. Mech. E.	Proceedings of the Institution of Mechanical Engineers	London	Price varies; gnrly. 3/– per part
Proc. Roy. Phil. Soc. Glasgow	Proceedings of the Royal Philosophical Society of Glasgow	Glasgow	10/6
Pub. Health Eng.	Public Health Engineer	London	–/6
Pub. Wks.	Public Works	London	1/2
Quarry	The Quarry	London	–/7
Rev. Tech.	La Revue Technique	Paris	2/–
Rlrd. Gaz.	The Railroad Gazette	New York	1/4
Rly. Age	The Railway Age	Chicago	1/4
Rly. & Engg. Rev.	The Railway and Engineering Review	Chicago	1/4
Rly. Mastr. Mech.	Railway Master Mechanic	Chicago	1/4
Rev. Chim. Ind.	La Revue de Chimie Industrielle	Paris	1/4
Rev. de la Métall.	Revue de la Métallurgie	Paris	...
Sch. Mines Quarty.	School of Mines Quarterly	New York	3/–
Sc. Amer.	Scientific American	New York	1/–
Stahl u. Eisen	Stahl und Eisen	Dusseldorf	1/–
Steamship	The Steamship	Leith	1/–
Stev. Inst. Indic.	Stevens' Institute Indicator	Hoboken, N.J.	2/6
Street Rly. Jnl.	Street Railway Journal	New York	2/6
Street Rly. Rev.	Street Railway Review	London	2/–
Surveyor	Surveyor	London	–/4
Techy. Quarty.	Technology Quarterly	Boston	5/–
Tek. Tidst.	Teknisk Tidskrift	Stockholm	1/–
Tek. Uged.	Teknisk Ugeblad	Christiania	1/–
Telephy.	Telephony	Chicago	1/–
Tram. & Rly. Wld.	The Tramway and Railway World	London	1/4
Trans. Am. I. E.E.	Transactions of the American Institute of Electrical Engineers	New York	Price varies
Trans. Am. I. Ming. Engrs.	Transactions of American Institute of Mining Engineers	New York	Price varies
Trans. Am. Soc. Mech. E.	Transactions of the American Society of Mechanical Engineers	New York	Mbrs. only
Trans. Am. Soc. Nav. E.	Transactions of the American Society of Naval Engineers	New York	30/–
Trans. Civ. Mech. E. Soc.	Transactions of the Civil and Mechanical Engineers' Society.	.....	Mbrs. only
Trans. Inst. Eng. & Shipbldrs.	Transactions of the Institution of Engineers and Shipbuilders in Scotland	Glasgow	Price varies
Trans. Soc. E.	Transactions of the Society of Engineers	.....	Mbrs only
Westn. Electn.	Western Electrician	Chicago	1/4
Zeitschr. Vereines Oster. Ing. und Arch.	Zeitschrift des Oestereichischen Ingenieur und Architekten-Vereins	Vienna	1/4
Zeitsch. Vers. Deutsch. Ing.	Zeitschrift des Vereins Deutscher Ingenieure	Berlin	2/–
Zeitsch. Elektrotechnik.	Zeitschrift fur Elektrotechnik	Vienna	1/4
Zeitsch. Elektrochemie	Zeitschrift für Elektrochemie	Halle a S., Germany	2/–

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MATERIALS AND MEASUREMENTS.

Diagram for finding the Diameter of Ball Bearings.

THE accompanying diagram furnishes a ready means for making the necessary calculations relating to ball-bearing construction. Sines for $\frac{180^\circ}{N}$ from 7 up to 26 have been found, and their values located on the vertical scale with the corresponding number of balls opposite. From the values of the sines, diagonals are drawn intersecting the horizontal scale at the reciprocal of the given sine. The diameters of the balls are found on the vertical scales, and may be read as whole inches instead of tenths, as marked in the diameter. Given the diameter and number of the balls, to find the inside diameter of the race: Find the intersection of the value of the diameter of the balls on the vertical scale, with the diagonal from the given number of balls, and read the result on the horizontal scale. This will be the diameter of the locus, to which add the diameter of the ball, and the sum will be the inside diameter of the race. Diameters which do not intersect with the diagonal from the required number of balls on the left-hand scale will be found to intersect with the diagonal from the right-hand scale, the result then being read on the lower horizontal scale. Another method of using the diagram is as follows: In the designing of a ball bearing, the principal known factor is usually the diameter of the shaft passing through the bearing. Suppose we have a shaft 1·5 in. diameter, with a clearance between shaft and balls of 0·225 in. and the diameter of the balls 0·75 in. The diameter of the locus will now be 1·5 in. + 0·45 in. + 0·75 in. = 2·7 ins. Find the intersection of the line from the value 2·7 ins.

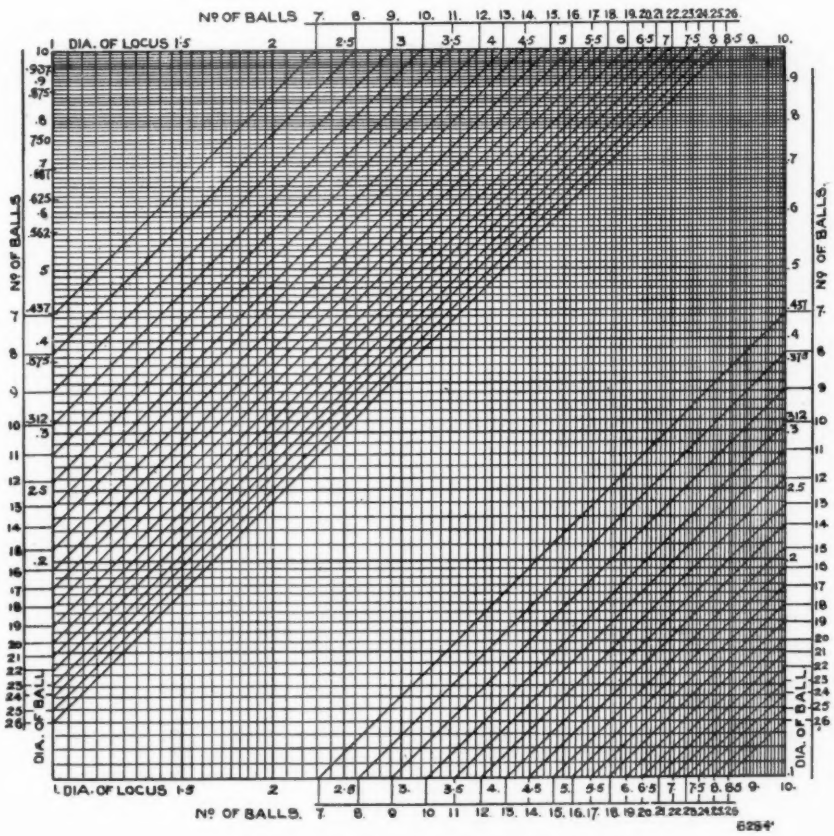


DIAGRAM FOR FINDING THE DIAMETER OF BALL BEARINGS.

on the upper horizontal scale with the diagonal nearest to the intersection of the values 0·75 in. and 2·7 ins. The diagonal for eleven balls will intersect with the lines from the values 2·7 ins. on the upper horizontal scale and 0·7525 in. on the vertical scale, which is correct, as it gives a clearance per ball of 0·025 in. More or less clearance may be had by increasing or diminishing the space between the shaft and balls.—**P. S. Bushnell,** *Amer. Machst., Vol. XXVI, No. 46,* pp. 1592–1594.

Testing Liquid Lubricants.

After discussing the different conditions to be satisfied by a suitable lubricating oil, the author enumerates the physical properties of these oils to which, in the first place, the diminution of the friction is due. The most important point is the necessity of choosing, in each special case, an oil of a consistency such as corresponds to the pressure on the axles and the temperature of the bearings, so as to prevent undue friction of the sliding surfaces. Of the oils thus classified, those which for the same consistency show the smallest resistance with regard to the internal friction should be preferred. In order to test the different oils from this point of view, the Berlin Allgemeine Elektricitäts-Ges. has designed a special apparatus, being based on a process patented by the author. The results of a large series of experiments are represented graphically.—**K. Wilkens,** *Paper read before the Elektrotechnischer Verein, Berlin, Elektrotechn. Zeitschr. Vol. XXV, No.* 7, pp. 135–139.—*A. G.*

ENGINEERING PHYSICS.

Steam Tension for Temperatures above 100 degs.

The tables used in practice for the tension of water vapour for temperatures of 100 degs. Cent. and upwards are based on Regnault's researches. The author has corrected some calculating mistakes made by Regnault, as well as some fundamental errors, the French experimenter not having used normal degrees and normal pressures. The annexed table contains the tension of steam for pressures of whole atmospheres and whole values of kg.-sq. cm., as resulting from this corrected Regnault table. — **H. F. Wiebe,** *Zeitschr. Vers. Deutsch. Ing., Vol. XLVIII, No. 9, Feb. 27, 1904,* pp. 315, 316.—*A. G.*

Electrical Foucault Pendulum Systems.

In Foucault's pendulum experiment to show the rotation of the earth, the oscillations of the pendulum gradually decrease in magnitude and finally die away altogether, so that, unless a very long pendulum is available, the observation of the rotation of the earth is limited to a short period. To remove this disadvantage it is necessary to provide some means of keeping the pendulum in constant and steady vibration by applying an accelerating force without in any way interfering with its free movement, and in this paper the author describes some electrical methods of attaining this end. The pendulum bob has a coil mounted on it with its axis in the line of suspension of the pendulum, *i.e.* the coil is horizontal when the pendulum is at rest. Directly underneath the pendulum, and with its centre directly under the point of suspension, there is mounted another coil of large dimensions, and the two coils are connected in series with each other and with a source of electromotive force and a controlling key. The principle of action is that when direct or alternating currents pass simultaneously through the two coils in the same direction the pendulum coil is repelled towards the centre of the larger coil, whatever be the plane of oscillation of the pendulum, and the repulsion is strongest when the pendulum coil is directly over a portion of the large coil. Thus by closing the controlling key when the bob begins to travel back to the central position, an accelerating force is applied which serves to keep the amplitude of vibration constant. The frequency with which the key should be closed depends on the length and weight of the pendulum, on the amplitude of vibration, and on the dimensions of the coils and strength of current. The connections for the pendulum coil are at the point of support of the system, and a twin con-

Steam Tension for Temperature above 100 Degs.

Tension.		Temperature in degs. Cent.	Tension.		Temperature in degs. Cent.
At.	Mm.		Kg.-sq. cm.	Mm.	
1	760	100·00	1	735·7	99·09
2	1520	120·60	2	1471·4	119·58
3	2280	133·91	3	2207·0	132·80
4	3040	144·00	4	2943·0	142·83
5	3800	152·22	5	3679·0	151·01
6	4560	159·22	6	4414·0	157·96
7	5320	165·35	7	5150·0	164·04
8	6080	170·82	8	5886·0	169·47
9	6840	175·77	9	6621·0	174·39
10	7600	180·31	10	7357·0	178·90
11	8360	184·51	11	8093·0	183·07
12	9120	188·42	12	8828·0	186·95
13	9880	192·09	13	9564·0	190·59
14	10640	195·54	14	10300·0	194·02
15	11400	198·80	15	11036·0	197·26
16	12160	201·91	16	11771·0	200·34
17	12920	204·87	17	12507·0	203·28
18	13680	207·69	18	13243·0	206·08
19	14440	210·40	19	13978·0	208·77
20	15200	213·01	20	14714·0	211·36
21	15960	215·52	21	15450·0	213·85
22	16720	217·94	22	16186·0	216·24
23	17480	220·27	23	16921·0	218·56
24	18240	222·53	24	17657·0	220·81
25	19000	224·73	25	18393 0	222·98
26	19760	226·85	26	19128·0	225·09
27	20520	228·92	27	19864·0	227·14
28	21280	230·93	28	20600·0	229·13
29	22040	232·88	29	21336·0	231·07
30	22800	234·78	30	22071·0	232·96

centric conductor passes down from that point to the coil. In a modified arrangement the electric circuit is more complex, and contains an induction coil with make-and-break device to provide a means of automatically closing the circuit when the pendulum coil comes directly over the large coil. In yet another arrangement the automatic means of operating the pendulum system is provided by a controlling contact mechanism, which, adjusted in synchronism with the pendulum, sends impulses of current to the coils when the bob is moving to the central position. All the details of the different arrangements are fully described and illustrated. — **E. K. Adams,** *Elec. Wld. & Engineer* (*N. Y.*), *Jan. 30, 1904, Vol. XLIII*, pp. 211–215.—*W. C. H.*

Motion of Gases in Pipes, and Use of Gauges to determine their Delivery.

In this paper the author makes a detailed investigation on the measurement of the velocity of gases flowing in pipes by means of the Pitot tube. He examines the influence of the shape of the Pitot gauge tip on the pressure set up; the reliability of side gauges; the relation between the velocity of air currents and the pressure developed in Pitot and other gauges; the distribution of velocity (on the cross-section of the pipe) considered as a function of the velocity itself, and comparison of the results obtained when measuring streams for delivery by the Pitot tube, with the actual volume of gas delivered as measured by a gas-holder; and finally, he considers some applications of the results obtained to actual engineering problems, and describes a new system of inferential gas-meters. The details of the investigation under each of these subdivisions are given in separate appendices, while the paper gives a general summary of the conclusions to be drawn from them. With regard to distribution of velocity, the author sets out in tables and on curves the results of his investigation, using a 6-inch cast-iron pipe fed from a gas-holder, and working with air-velocities in the pipe, ranging from 1,320 ft. to 2,470 ft. per minute. An inspection of these tables leads him to the following conclusions:— (1) The radius of the circle of mean velocity is about 0·775 of the radius of the pipe through which gas is flowing, in the case of pipes which are not infinitely long, but comparable in length with those employed in connection with gas-producer plants. (2) In one case of a gas main 15·75 ins. in diameter, examined at a distance of about 10 yds. from the nearest bend, the radius of mean velocity was about 0·9 of the radius of the pipe. (3) In no case was a radius of mean velocity actually found as low as 0·689, which is the value given by Darcy for the case of water flowing through a long smooth pipe. (4) The distribution of velocity remains unaltered through a wide range of velocity covering the cases occurring in actual practice. (5) The ratio of mean to maximum velocity is unexpectedly constant over a wide range of velocity and very varied mode of distribution, and has an average value of 0·873. The object of this investigation was to find the best means of measuring the delivery of producer-gas by large mains. The concluding portion of the paper is devoted to a description of a gas-meter working by Pitot pressure, in which the pressure difference is always exactly balanced by the electro-dynamic force between movable and fixed coils. The current in these coils flows through an ampère-hour meter, whose reading gives the number of cubic feet of gas delivered.—**R. Threlfall,** *Paper read at Inst. Mech. Engineers, Feb. 19, 1904.* —*W. C. H.*

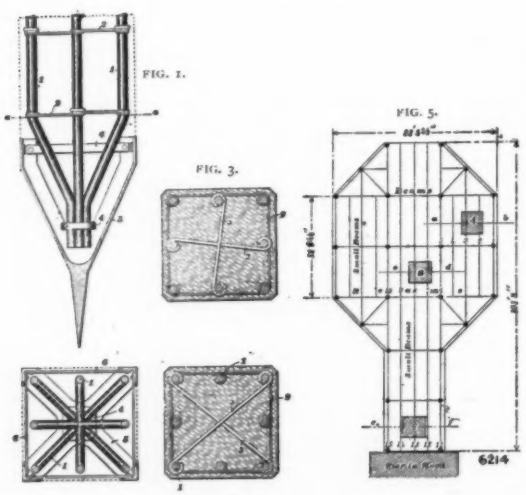
Theory of Radio-active Phenomena.

THE theory proposed in this paper is based on the hypothesis that electrons, in connection with chemical equilibrium phenomena, and more particularly in the equilibrium between oxygen and ozone, are controlled by the law of mass effects (law of Guldberg and Waage). In a previous paper the author had pointed out that ozone behaves like a radio-active body, and that on being dissociated—*i.e.* converted into oxygen—will become a conductor of electricity, giving off gaseous ions; on the other hand, its formation takes place in connection with certain electric phenomena whenever gaseous ions are present. This is thus a reversible process; and if gaseous ions be considered as material particles, ozone may be said to be formed from oxygen and gaseous ions; that is, to be a *chemical compound* of electrons and oxygen, or else an *electronide* of oxygen, both electrons and atomical ions being controlled by the mass law in the same way as electrolytic ions and electrically neutral molecules. As the equilibrium constant of this reaction will decrease for increasing temperatures, the constancy of ozone must augment in proportion; the concentration of the gaseous ions given off from ozone will equally be smaller than with low temperatures. The author allows for the well-known fact that strongly active radium compounds will give off a small amount of ozone by the ionisation of air due to the gaseous ions given off from radium, in virtue of which ozone is produced from the surrounding oxygen. The hypothesis is suggested that radium and analogous substances are also "electronides." It is thought probable that radio-active substances were produced by volcanic phenomena, attended by violent evolutions of electricity. As in many slow reactions, such as the oxidation of organic substances, giving rise to the formation of ozone, the presence of gaseous ions has lately been ascertained, it is probable that many, if not all, chemical reactions are attended by the presence of such gaseous ions in variable amounts. After enunciating the hypothesis that the "emanation" of radio-active substances is nothing else than ozone, the author tries to account for the excited radio-activity phenomenon by the action of ozone, to which would equally be due the phenomenon of spontaneous dispersion of electricity, as observed in dwellings and caves (where putrefaction and decomposition processes are more intense), with a much higher intensity than, for instance, in certain mines. — **R. Schenck,** *Paper read before the Prussian Academy of Sciences, meeting of Jan. 7, 1904;* see *Sitzungsberichte, 1904*, pp. 37–46.—*A. G.*

CONSTRUCTION.

Concrete Metal Construction.

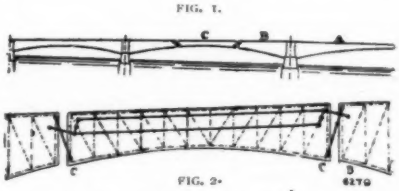
In the wharf constructed at Novorossisk, on the Black Sea, the piles are 15¾ ins. by 15¾ ins. by 42 ft. long, and weigh 262 lbs. per lin. ft. The reinforcement of the pile (Figs. 1 and 2) is composed of eight bars of round iron, bound together every 10 ins. by bands and by diagonal ties joining the corner or the middle bars alternately, as in Figs. 3 and 4. Russian cement and silicious sand were used for making the concrete, which was mixed with sea water. The piles were constructed horizontally, and exposed to the atmosphere for several days, at the expiration of which they were immersed in water, where the process of solidification was completed. Driving was accomplished in the following manner. After dropping the pile into position from a height of about 14 ft. the hammer, weighing 3,375 lbs., was dropped from a height of 12 ft. to 14 ft. upon the head of the pile, striking an average of 12 blows in each case until the penetration reached about 2 ft. The piles were made about 6 ft. longer than the depth of the soundings showed to be actually necessary. In levelling the heads of the piles the concrete only was removed, and the protruding bars were then bent over and locked with the armoured concrete stringer, afterwards built from pile to pile, of which Fig. 5 is a plan. The beams and braces of the wharf were of rectangular section, and the frames forming ties or tie rods were placed in their interior, being calculated to resist deflection, rupture, and shear. These beams and braces were constructed in one horizontal plane at 4 ins. above low water, and their dimensions were about 11¾ ins. by 7¾ ins. The construction here adopted obviated the possibility of shearing action caused by lateral efforts, to which the structure would be subjected if the braces had been placed at different levels. The advantages offered by concrete as compared with wooden piles are—(1) The contact of the water hardens them more and more; (2) their life is unlimited, and they require no repairs; (3) they are fireproof; (4) they can be used as columns to support heavy loads.—**E. Villet, C.E.,** *Jnl. Assoc. Eng. Soc., Vol. XXXI, No. 4,* pp. 115–126.



CONCRETE METAL CONSTRUCTION.

The Troitsky Bridge, St. Petersburg.

This bridge, which has a total length of 480 m. and a width of 23·50 m. between the balustrades, consists of two parts, (1) a swing bridge forming two steel spans, each providing an opening of 25·60 m., and (2) a fixed bridge of five steel spans, each forming a symmetrical arch—the centre opening being 96·50 m., and of the other openings, two measure 76·50 m. and



THE TROITSKY BRIDGE, ST. PETERSBURG.

two 53·50 m. each. The central span is a three-hinged braced arch, the ends being carried away by cast-iron skewbacks provided with steel rollers. The end spans consist of braced girders of an arched form, and the intermediate spans are formed by braced cantilevers projecting from the centre and the two end spans, joined by suspended girders. The general method of construction is shown in Fig. 1, where *A* is half the central span; *B* is a cantilever which supports one end of the connecting girder *C*, and counterbalances part of the weight of *A*, consequently diminishing the thrust that would be experienced if *A* existed alone. Fig. 2 shows the method adopted for the suspension of the connecting girders of the two intermediate spans. The piers are of rough ashlar, faced with dressed granite, and were nearly all built in pneumatic caissons—the abutments and one pier having been built on piled foundations. The abutments are of concrete enclosed in masonry walls. The roadway of

the fixed part of the bridge is formed of wood blocks on double planks embedded in asphalt—the whole resting on a bed of concrete, supported by buckled steel plates; but on a portion of the roadway devoted to tramway lines the wood blocks are replaced by granite sets. The foot-walks are paved with limestone flags laid on a bed of concrete, supported by buckled steel plates. On the swing bridge, both roadway and foot-walks are paved with wood to lighten the construction and to facilitate the working of the bridge. Three granite arches, with spans of 24 m., 22 m., and 20 m. respectively, were built on the right bank of the river, as it was feared that any diminution in the width of the stream would lead to the deposition of silt. The swing bridge consists of two braced cantilevers, suitably connected at the centre, rotating on a series of rollers on the cap of the masonry pier, which is furnished with a cut-water on the up-stream side. The swing span is operated by means of chain gear driven by an electric motor-control of the mechanism being afforded by levers fixed at the two extremities of the span. A fully detailed description of the bridge—as well as the methods followed in its construction—are given by the author, together with several drawings and photographic views showing the progress of the work. The works were commenced in April, 1898, and the bridge was opened for traffic in November, 1902, the total cost having been about £560,000.—**P. Bodin,** *Gén. Civil, Vol. XLIV, No. 12,* pp. 177-183.

Brick-Making Plant.

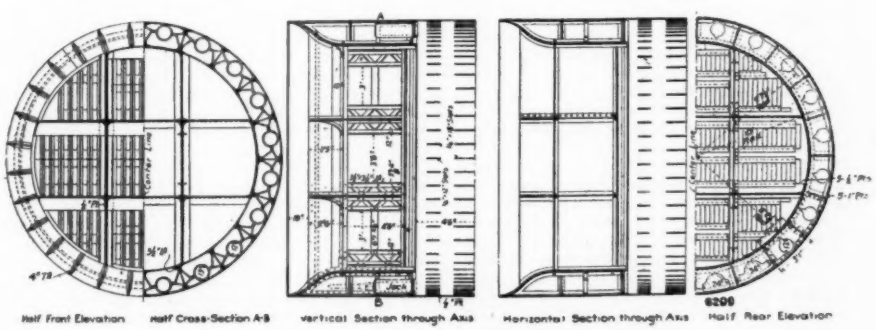
In this article, which is devoted to a description of the plant of the Western Brick Co., at Danville, Ill., the author first deals with the nature of the strata encountered on the site. He then describes the method of excavating the shale, which is found in large quantities in that part. After giving an account of the process of brick burning, the paper is concluded by tables showing the results of tests made at the University of Illinois on ordinary building brick, together with two reports by Prof. A. N. Talbot, of the same university, one referring to these tests and the other to some tests of paving brick.—**Anon.,** *Eng. News, Vol. LI, No. 2,* pp. 30–32.

Record of the Fireproof Buildings in the Baltimore Conflagration.

In this conflagration, which swept the city of Baltimore, and laid in waste its entire wholesale business and banking district, 99 per cent. of the buildings in the burnt district were of the kind whose destruction was a foregone conclusion. In the few buildings of steel cage fireproof construction the framework is intact and plumb, and with a new member in one or two places will be as good as new. In all of them the exterior walls are structurally sound, although exhibiting surface blemishes due to spalling in all but one; 90 per cent. of the floor arches are intact, and not more than a quarter of the remaining will have to be rebuilt; in all every window is gone, and every item of finish and contents has been destroyed; in all ignition resulted from the flames of adjacent non-fireproof buildings breaking through the unprotected windows.—*Eng. News, Vol. LI, No. 7,* pp. 145–8.

An Improved Tunnelling Shield.

The shield here described was designed for the Thirty-ninth-Street conduit, Chicago, and has lately been developed for application to tunnels, with the object of overcoming the numerous difficulties encountered in submarine tunnelling and in some land tunnelling, particularly beneath streets lined by heavy buildings. Each shield is essentially a double tube, having two steel-plate shells, with a bell-shaped reducing plate extending from the cutting edge to the forward end of the inner shell, bulkheads and controlling gates of special design, and interior partitions and framework, which can be left out if desired. The general construction of the shield is shown in the illustrations reproduced. The hydraulic jacks are carried in cells formed between the shells by stiffening plates by means of bent plate carriers connected to the shells through the same angles as the stiffening plates, as shown. The cutting edge has a small bevel outwards, while the bell-shaped reducing plate, as indicated in the



AN IMPROVED TUNNELLING SHIELD.

drawings, produces considerable compression of soft materials in reducing the diameter of the intercepted cylinder of earth. If the soft material has a tendency to move in advance of excavation, the forward movement of the shield causes it to be deflected against the bulkhead and held intact until excavated. In shields of large size this reducing space in front of the bulkhead can be subdivided by vertical and horizontal partitions, which are placed to correspond in position with vertical and horizontal partitions inside the shield, carrying the working platforms. These interior walls are of heavy steel plate, and are arranged to divide the space inside the shield into as many working chambers as the size of the tunnel may require. The bulkhead is pierced by one or more hinged doors, corresponding to the working chambers, swinging back against the partitions, or in small shields against the inside of the shell. The doors are provided with strong latches, and each door has several narrow vertical slots, as shown, controlled by a sliding gate. Over one or more slots in each working chamber nozzles may be fitted into the sliding gate to provide for the attachment of a centrifugal pump. To aid in breaking up strata of tough clay or other solid formations, a number of radial 4-in. steel tees are riveted to the face of the bell-shaped reducing plate, from the cutting edge to the plane of the partitions in front of the bulkhead. Wherever the tunnel is in a formation sufficiently stiff to be self-sustaining, the bulkhead may be entirely removed to permit of blasting, if necessary. The shield is followed by a steel-plate apron, so attached as to make the outer surface flush. Numerous narrow slots give it a slight degree of flexibility. By means of a special group of cocks supplied with a gauge, the pressures exerted on individual jacks may be ascertained, thus making it possible to direct the application of pressure so as to keep the shield to line and grade. The type of shield described can also be adapted to cross-sections of the horseshoe, or similar shapes.—**Anon.,** *Eng. Rec., Vol. XLIX, No. 1,* pp. 13–14.

The Williamsburg Bridge, N.Y.

THIS series of four articles gives a very complete and detailed account of the new bridge across the East River. Part I. deals with the design of the structure, and contains a general description and details of the truss members. Part II. describes the erection of the lower chords and floor, the distribution and erection of truss members, power and air plants, and of the yards and power plant. Part III. is devoted to the description of the steel hoisting-derricks and main travellers. Part IV. is a classified schedule of erection, riveting, and special apparatus; measurements, adjustments, and final connections. This part also deals with the progress of the work, the handling and riveting of members, the measurements and adjustments of the suspended span. The article is illustrated by numerous drawings and diagrams of various parts of the work.—**Anon.,** *Eng. Rec., Vol. XLVIII, Nos. 25 and 26,* pp. 756–757 and 809-810; and *Vol. XLIX, Nos. 1 and 2,* pp. 14–18 and 40–41.

Towers and Anchorages of Manhattan Bridge, New York.

THIS article is devoted to a description of the towers and anchorages of the Manhattan Bridge now being constructed across the East River at New York. The towers will have pneumatic caisson foundations, and the long spans between them and the anchorages will be suspended from the shore ends of the eye-bar chains. The anchorages are rectangular masses of masonry with their foundations carried down to a level about 15 ft. below the mean high-water level, and built in open pits. Having described the construction of the towers in detail, the writer concludes by briefly mentioning the floor-beams, concrete sidewalks, and the platform. The article is accompanied by drawings illustrating the details of the anchorage and the main towers.—**Anon.,** *Eng. Rec., Vol. XLVIII, No. 24,* pp. 730–732.

The Erection of Iron Bridges.

THE question of the temporary work for the erection of iron bridges is of as much importance as any other part of the design of the structure. In large bridges the erection alone will probably cost as much as the ironwork, and the proposed method of erection should always be considered as part of the design of the bridge itself. In tropical countries, or in any place where rivers are liable to sudden floods, quickness of erection is often of paramount importance, as it may be also in the renewal of existing railway bridges. Almost every type of bridge can, if needful, be erected by means of temporary girders, protrusion, or some other means of building out, without fixed staging from the ground below; but in each case it should be considered whether such staging would not be really more economical in the end. The cost of labour and of materials, and the possibility of securing trained labour of sufficient amount and quality are important factors, especially in foreign countries and in the colonies. Bridges and the methods of their erection may be classified as follows:—IA., girders, on staging; IB., girders, by floating out; IC., girders, by pushing over sideways; ID., girders, by lifting bodily; IE., girders, by protrusion of temporary stage; IIA., continuous girders, by rolling out; IIB., continuous girders, by various means of erection; III., cantilever, by building out; IV., metal arches, by building out; V., special methods. Method IA. is the earliest system of bridge erection. Its great advantage is in the facility with which the work of construction is afterwards done. Safety, convenience, and certainty are also important points to be considered. The disadvantages are the great cost, and sometimes the danger arising from floods or ice. The following bridges are referred to as examples:—Allgyo, Kuilenburg, Bommel, Empress bridge over the Sutlej, and some others. Method IB. has many advantages, but some risk must be taken during the execution of the work. A large quantity of plant, such as tugs, winches, barges or pontoons, is required. Many bridges have been partly protruded and partly floated out, and advantage may be taken of the tides for the raising and lowering of the

pontoons. When the plant can be used again for other purposes, this system may perhaps be the cheapest method of erecting large girders. The following examples are mentioned:—Moerdyk bridge in Holland, Syzrain bridge, Hawkesbury bridge, New South Wales, also the Hugli bridge, the Niagara, Niemen, and Tay bridges. Method Ic. is much used for the renewal of existing bridges where traffic has to be maintained. A staging is generally prepared on both sides of the bridge to be reconstructed; on the one side to receive and prepare the new structure before it is pushed over into its position, and on the other side for receiving the old structure after its removal from the bridge, and for taking it to pieces. The examples referred to are:—The Hernad and Lomna bridges, the Prater bridge near Vienna, the Tornocz bridge, and the Delaware bridge at Trenton. Apparently the simplest, but in some cases really the most complicated, system of construction is Method Id. Great care has to be taken in the handling and lifting of large girders in one piece, as there is great danger of straining and so injuring the metal. The advantages are that the riveting will probably be much better done at the contractor's yard than in the field, as in the case of building out, etc. Reference is made to:—Railway bridge near Mainz, the Crumlin, Meldon, and St. Pinnock viaducts, the Saltash bridge, and the temporary footbridge alongside London Bridge. Method Ie. is not often employed, and is used only where there is unusual danger from floods, etc. Generally, where the method of protrusion is adopted, the girder is designed as continuous, and is protruded without any other scaffolding. To avoid ambiguity in stresses, the girders so protruded may be cut after erection at the points of contra-flexure, and so formed into a cantilever structure. This class could, perhaps, with advantage, be included in Class V. The case of the Regoa bridge is referred to. Method IIa. is probably the most advantageous method for the erection of the continuous girder, the chief advantages being that the use of staging is entirely obviated, and that the construction of the girders may be carried on without danger and in a sheltered position. The girders have to be made stronger in order that they may be protruded; that is, they have to be strong enough to carry their own weight at all positions whilst the protrusion is being accomplished. One source of danger is in the stress that must occur at the top of the piers during the progress, unless very special arrangements are made. The following cases are referred to: The Fribourg bridge, Switzerland; the Stadlau bridge, Vienna; the Dao viaduct, Portugal; and the Tardes viaduct. Method IIb.—Sometimes continuous girders are erected on staging; in other cases they are floated out, and the principle of continuity is, perhaps, effectively given by induced initial stresses; or a continuous girder may be built out from the abutments, the members being arranged to meet in the middle of the opening. In other cases the girders may be lifted bodily, and perhaps even lifted as the piers and supports are being built. In one case continuous girders have been moved sideways, and great care had to be taken that the ironwork was not strained injuriously in the operation. The following bridges are mentioned: The Znaim viaduct, Moravia; Bordeaux bridge; the Britannia Tubular bridge; the Irwell viaduct, on the Manchester Ship Canal; and the Approach viaduct, Forth bridge. Method III. has been adopted for the construction of some of the largest bridges in the world. The chief advantages are that scaffolding or staging is dispensed with. The greatest care must be taken with the setting out of the work, so that when the work from both sides meets in the centre of the opening there shall be no error at the junction. The temporary ties necessary to hold up the work during the progress are relatively of very small cost. The cases referred to are the Kentucky and Forth bridges. Method IV. is similar to the building out of a cantilever. Special means are discussed for effecting the accurate junction in the centre of the span. The following instances are given: El Cinca bridge, Spain; the St. Louis bridge over the Mississippi; the Douro bridge, Spain; and the Rio Grande bridge. Under the last heading (V.) reference is made to some processes which cannot be placed under either of the preceding classes. They include the construction of metal arches by the protrusion of a temporary stage, and of suspension bridges from suspended platforms.—**R. S. Scholefield, A.M.Inst.C.E.,** *Proc. Inst. Civ. Eng., March, 1904.*

METALLURGY.

Proportions of Regenerative Gas Furnaces, with Special Reference to Open Hearth Furnaces.

Hearth Furnaces.—The fuel commonly used in these furnaces—producer-gas—is generated by the incomplete combustion of coal. One ton of coal will yield from 150,000 to 160,000 cub. ft. of gas at normal pressure and temperature. The cross-section of outlet from the producer, or sewers leading to the regulating-valve, should, according to Toldt, permit a velocity of 1 m. per second at a temperature of 300 degs. C. These requirements correspond to a free area of 0·6 sq. ft. for each 100 lbs. of coal burned in the producers per hour. *Stack.*—The quantity of gases drawn through a stack varies directly with the section, the maximum discharge occurring with a mean stack temperature of 522 degs. Fahr. The combustion of 100 lbs. of coal in the producer will yield 36,500 cub. ft. of stack-gases at 760-mm. pressure and 522 degs. Fahr. Both Toldt and Ledebur advise an average velocity of the stack-gases of 16½ ft. per second; in other words, 0·6 sq. ft. for each 100 lbs. of coal per hour. An average of 10 furnace-stacks gives approximately 0·95 sq. ft. for each 100 lbs. of coal per hour. *Air and Gas Valves.*—Gas from 100 lbs. of coal burning with 20 per cent. excess of air will require about 10,200 cub. ft. of air at 760-mm. pressure and 0 degs. Cent. If this combustion is effected in an hour, the air passing through the air-flue per second at 86 degs. Fahr. would be 3·14 cub. ft. This would require an air-valve opening of 0·31 sq. ft. for each 100 lbs. of coal burned per hour at

the producers, and a flue section of two-thirds the stack section. The 7,000 cub. ft. of gas yielded by 100 lbs. of coal per hour would require a gas-valve section of 0·26 sq. ft. *Regenerators.*—An examination of several furnaces shows the average contents of one air- and one gas-chamber to be 94 cub. ft. for each 100 lbs. of coal burned per hour; or approximately 1 cub. ft. per pound of coal per hour. *Air and Gas Ports.*—The total area of the air-ports at one end for each 100 lbs. of coal burned per hour will require a port section of 0·59 sq. ft.; whilst 7,000 cub. ft. of gas at 1,200 degs. Cent. will require 0·4 sq. ft. *Hearth.*—Ledebur states that in practice basic furnaces over 15 tons capacity average 7¾ sq. ft. of hearth section per ton of product, whilst acid furnaces average 6¾ sq. ft. per ton of product. If this surface is measured above the sill line, in American basic open-hearth practice the section will approximate that stated by Ledebur; the actual bath surface, however, will be between 5 and 6 sq. ft. per ton of metal charged, the usual depth being 15 to 18 ins.—**H. D. Hess,** *Proc. Engrs. Club of Philadelphia, Vol. XXI, No. 1,* pp. 48–65.—*P. L.*

The Testing of Cast-iron.

THE author in a paper presented to the New England Foundrymen's Association, discusses the influence of various factors on the properties of cast-iron. The selection of the section of a transverse test-bar depends upon two things: first, that it should be as large as possible, consistent with a uniform structure; and second, that it must come within the limits of the ordinary testing-machine. A series of test-bars, ranging from ½ ins. to 4 ins. in sectional area have shown that any section above 1½ in. diameter begins to show weakness in the structure, whilst below 1 in. the grain is unduly close. As it is desirable to make transverse tests on supports 12 ins. apart; and, as 5,000 lbs. is the limit of testing-machines in ordinary foundries, a bar 1¼ ins. diameter and 15 ins. long* appears to be the natural standard to work on.—**Dr. R. Moldenke,** *Iron Trade Rev., Vol. XXXVII, No. 7,* pp. 63–64.—*P. L.*

The Elastic Limit of Metals.

WHILST the smallest load on a test-piece will cause a slight permanent set, it is noteworthy that such structures as iron bridges retain their shape under variation of stress. Further, if a test-piece is subject to a small stress many times in succession, recovery after each application becomes almost perfect. What, then, is elastic limit? The Commission des Méthods d'Essai of 1894 announced that it is necessary to recognise three such limits: (1) the theoretical limit of elasticity, or the maximum stress which does not produce a permanent strain; (2) the proportional limit of elasticity within which the strain is proportional to the stress; (3) the apparent limit of elasticity corresponding to the "breaking down" point of ductile metals. Above this point, perceptible increases in deformation occur without a perceptible change of load. M. Frémont has shown that the exact difference between the first two cannot be defined, and there are also theoretical grounds for supposing that they ought to coincide. Moreover, the proportionality of deformation has been called in question, slight irregularities having been detected when the measurements were made with the greatest care. From a series of experiments M. Frémont has proved that the theoretical elastic limit is the mean charge per unit of section on which the real elastic limit is locally attained at a point of the piece tried. It is not the elastic limit of the metal, but of the particular piece of metal under the special conditions employed. The proportional elastic limit is still more fortuitous. Owing to compensating errors, the line showing the relation between stress and strain may continue to be fairly straight, even above the theoretical limit. The apparent limit is the mean charge per unit of section when the real elastic limit is reached. It is nearer the real limit, but it is not identical with it, because the charge is unequally distributed between the parts that have been previously hardened by stress, and those that are not yet hardened.—**T. K. R.,** *Nature, Vol. LXIX, No. 1,786,* pp. 276, 277.—*P. L.*

* This is the standard proposed by the sub-committee of "the American Society for Testing Materials" on "General Castings"; and it is interesting to note that round bars, instead of the square or rectangular bars usual to British practice, are advocated.

A New Metal-Melting Furnace.

IN a new type of oil-heated metal-melting furnace, recently installed at the foundry of the Lunkenheimer Co., Cincinnati, the drum is made of sheet steel with cast-iron heads, and is lined with fireproof tile, having two openings on opposite sides of the cylinder. Only one opening is in use at a time, the other being closed by a fireclay filling. A furnace of this type wears out more quickly around the filling hole than elsewhere; but when one hole is worn out this can be closed, the furnace reversed, and the second hole cut out and put in service. In this way the length of life of the lining is doubled. A special type of oil burner has also been employed to give the greatest amount of heat from a given quantity of oil. In the furnace employed at the Lunkenheimer foundry each heat averages about 550 lbs., and the consumption of fuel varies from 2 to 2½ gals. of crude oil per 100 lbs. of metal melted. Six and seven heats per working day of ten hours are secured from each furnace. The life of the linings is from 300 to 400 heats, depending considerably on the kind of metal melted. A simple form of tile is used for the lining, so that it can be easily inserted.—**Anon.,** *Eng. Rec., Vol. XLIX, No. 1,* p. 32.

Some Applications of Copper in Engineering Practice.

THE author, in a paper read before the Manchester Association of Engineers, discusses the various applications of copper. The advantages of this metal to engineers are found in its high conductivity for heat and electricity, its ductility, and in the resistance offered to corrosion. Unalloyed copper in the cast condition is of comparatively little use, and in order to realise the best combination of tenacity and ductility the metal must undergo

more or less mechanical work. The following tests, taken at various stages during the manufacture of a seamless copper tube, show the value of this work. As cast in an iron mould the tensile strength of the copper was 10·5 tons per sq. in., with an extension of 25 per cent. on 4 ins. After undergoing a certain amount of hot forging the tenacity rose to 12·5 tons per sq. in. and the extensibility to 35 per cent. on 4 ins. Further forging gave a tenacity of 14·1 tons per sq. in. and an extensibility of 50 per cent. on 4 ins.; and after cold drawing the results were—tenacity, 15·2 tons per sq. in., with an extension of 48 per cent. on 4 ins. After alluding to sources of deterioration, such as overheating and "gassing," the author passes on to the various applications of copper. In the case of locomotive fire-boxes, stays, and tubes the beneficial influence of arsenical copper is shown, and the utility of a standard content of arsenic suggested. Of the alloys used in locomotive practice the following comparative tests are given:

Material.	Tensile Strength in Tons per Sq. In.	Extension % on 8"
Copper, hardened a little by rolling	17·8	27·0
Copper, annealed ...	14·6	49·0
Brass, 60 Cu. 40 Zn., anld.	22·8	47·5
„ 70 „ 30 „ „	20·7	60·0
Manganese bronze, „	30·0	15·0
Aluminium copper, 5% Al. annealed	24·0	69·0
Aluminium copper, 8·5% Al., annealed	31·4	57·9
Koro metal tubes, annld.	17·6	44·0
„ „ „ hardnd.	28·2	5·4

—**W. E. Storey,** *Mech. Wld., No. 884,* pp. 278, 279; *No. 885,* pp. 291, 292; *No. 886,* p. 305; *No. 887,* pp. 9, 10.—*P. L.*

Styrian Steel.

THE author traces the history of Styrian steel, showing the interesting link connecting the extensive works of Bohler Bros. at Styria with the remote past. The ore mountain, Erzberg, situated between the villages of Eisenrz and Vordenberg, had been surface-mined for nearly 3,000 years. The conquering Roman legions had produced their famous "Noric iron" from the spathic ore quarried from the Erzberg, this iron ore being acknowledged by metallurgical experts to be of special purity, the phosphorus, sulphur, and copper being exceedingly low, whilst the manganese is relatively high. The immense pine-wood forests, covering 60 per cent. of the total area of Styria, enabled the Styrians to smelt their pure spathic iron ores entirely with charcoal fuel, producing a white cast-iron. The subsequent treatment which the cast-iron received in the old Styrian open hearth resulted in the production of a refined steel in which the impurities do not exceed 0·03 per cent. Thus the excellent properties of Styrian steel, especially the readiness with which even some of the high-carbon varieties can be safely welded, could be accounted for by the remarkably low percentage of impurities.—**R. B. Hodgson, A.M.I. Mech.E.,** *Proc. Birmingham Assoc. Mech. Engr., March, 1904.*

The Bottom of a Green-Sand Mould.

THE author, in a paper presented to the New England Foundrymen's Association, discusses the difficulties of green-sand moulding, and urges the necessity for more systematic methods. An ingenious device for testing the hardness of the face of a mould is also described, and the method advanced as a probable aid to greater uniformity.—**T. D. West,** *Engineering, Vol. LXXVII, No. 1,984,* pp. 64–66.—*P. L.*

The Brittleness of Steel.

IN the case of metals which are always either normally brittle or malleable a sufficient index of their properties may be obtained in the elongation resulting from a tensile test. The assumption that this test is sufficient in the case of iron and steel has led to error, for in many cases of accidental fracture the metal had previously shown much ductility under the tensile test. These accidents have been explained by local defects or the presence of flaws, but in the majority of cases no trace of either could be found. Further explanations have attempted to show that the constant use of the metal resulted in some alteration of its condition, but tensile tests taken from the vicinity of the fracture have always shown this hypothesis to be incorrect. The explanation of these accidents must be looked for in the intermittent brittleness of the metal, a brittleness not shown in the tensile test, but evidenced in the working life of the metal. The brittleness of steel may be traced to two different causes:—(1) The nature of the metal; in other words, its chemical composition, structure, presence of foreign substances, such as slag, blowholes, etc. (2) External conditions prevailing whilst the metal is subjected to stress, which must cause its rupture, as the suddenness of the application, the external shape of the piece, temperature, etc. In reviewing the first cause, the influence of composition, constitution, structure, casting temperature, heat treatment, and hot and cold working are indicated. Of the external conditions the following are noted:—*Impact.* It is known that a sudden shock will produce fracture more readily than a slowly applied stress. This is because the maximum strain produced by impact increases rapidly as long as the distortion of the metal remains slight, which is the case during the period of elasticity. Shock develops strains superior to the elastic limit, which are not readily produced by slowly applied stress. *Temperature.* Experiments have shown that iron and steel are more brittle at low temperatures than normal ones. Soft steels, which at ordinary temperatures have shown brittleness, may lose this property when heated to 300 degs. Cent. *Shape of*

piece. The angular parts of a test piece are like so many points of weakness, having a tendency to break with very little if any distortion, and are therefore a cause of brittleness. This fact is utilised in testing for brittleness by nicking a bar, and subjecting it to a drop test having a tendency to open the cut. In this manner fracture takes place without distortion, and the more readily the sharper the cut. With a cut having a width of a few hundredths of a millimetre only at the bottom brittleness is exhibited by half of the extra mild steels manufactured. In almost every case, however, brittleness in these soft steels disappears completely when they are subjected to a suitable thermal treatment.—**Prof. Le Chatelier,** *The Iron and Steel Metallurgist, Vol. VII, No. 2,* pp. 125-134.—*P. L.*

Iron and Steel Alloys.

THE author gives a *resumé* of his extensive researches on the influence of various elements upon the metal iron. The comparative mechanical properties of these alloys are shown in the accompanying table :—

COMPARISON TABLE OF FORGED ALLOYS, ALL THE MATERIAL BEING IN THE ANNEALED CONDITION.

ALLOY.	C. %	Si. %	Al. %	Cr. %	Ni.		Elastic Limit. Tons per sq. in.	Breaking Load. Tons per sq. in.	Elongation % on 2 ins.	Reduction of Area %	Bending Angle.
Silicon A.	0·14	0·24	..	...	..	...	15·17	25·00	37·55	60·74	Double
Aluminium A.	0·15	...	0·38	...	...	...	20·00	26·00	40·35	60·74	,,
Chromium B.	0·16	...	...	0·29	...	...	17·00	25·00	45·55	65·90	,,
Nickel A.	0·19	...	...	...	0·27	...	20·00	28·00	37·05	52·14	,,
Tungsten B.	0·15	...	...	...	...	W. 0·20	16·50	22·00	46·30	66·48	,,
Copper 124%	0·19	...	...	...	...	Cu. 0·40	24·00	43·00	21·45	28·22	,,
Silicon B.	0·18	0·73	...	..	...	...	19·00	29·50	34·02	52·66	Double
Aluminium C.	0·18?	...	0·66	...	...	...	18·00	27·00	33·00	52·14	,,
Chromium E.	0·12	...	...	0·84	...	...	19·00	28·00	42·50	61·20	,,
Nickel C.	0·13	...	...	..	0·95	...	20·50	27·00	41·75	63·36	,,
Tungsten E.	0·21	...	...	..	...	W. 0·81	18·00	26·25	37·60	53·26	,,
Copper 124%	0·25	...	...	...	...	Cu. 1·39	32·00	43·00	31·41	50·92	,,
Silicon C.	0·19	1·60	...	...	...	...	25·00	33·00	35·10	54·52	Double
Aluminium F.	0·21	...	1·60	...	...	...	13·00	26·00	36·35	67·00	,,
Chromium G.	0·21	...	...	1·51	...	...	19·00	33·50	38·07	55·88	,,
Nickel D.	0·14	..	...	...	1·92	...	22·00	31·00	36·26	53·70	,,
Tungsten G.	0·21	...	...	...	...	W. 1·49	19·50	28·50	36·90	54·88	,,
Silicon D.	0·20	2·18	...	...	...	...	25·50	34·00	36·50	59·90	Double
Aluminium H.	0·24	...	2·24	...	...	...	18·50	28·50	33·00	48·62	,,
Chromium H.	0·39	...	...	2 54	...	...	24·50	44·00	24·50	33·84	,,
Nickel E.	0·19	..	...	...	3·82	...	25·00	33·00	35·85	55·86	,,
Tungsten A.	0·28	..	..	.	...	W. 3·40	23·00	34·00	33·90	53·02	,,
Copper A/2	0·23	...	...	...	...	Cu. 2·72	23·00	33·50	29·95	45·14	,,
Silicon II.	0·26	5·53	...	...	...	...	25·00	25·00	0·37	2·00	Would not bend
Aluminium I	0·22	...	5·60	...	...	..	27·00	36·00	6·45	6·16	16° broken
Chromium J.	0·77	...	...	5·19	...	...	20·00	55·00	8·20	6·88	Double *
Nickel F.	0·18	...	...	...	5·81	...	28·50	37·00	33·15	51·62	,,
Tungsten I.	0·38	...	...	...	...	W. 7·47	24·00	40·00	25·65	38·46	,,
Copper B.	0·16	...	...	...	..	Cu. 4·40	Would not forge.				

* Carbon in chrome sample too high to make direct comparison.

The influence of titanium upon iron has not yet been accurately determined. Apparently it acts in a similar manner to aluminium by absorbing the gases present in the metal; but the product appears to be of no special value, and after 0·3 per cent. is exceeded the physical qualities are unfavourably affected. Experiments with molybdenum show that its influence on iron is similar to that of tungsten, though a much lower percentage is necessary to produce the same effect. The author was the first to produce cobalt steels, and his experiments show that this material gives results similar to nickel steels in that the elastic limit and breaking load are raised. A series of results obtained from cobalt steels are shown in the following table:—

TESTS OBTAINED FROM FORGED MATERIAL.

Mark.	Analysis.						Unannealed.				Annealed.			
	C.	Si.	S.	P.	Mn.	Co.	Elastic limit. Tons per sq. in.	Breaking load. Tons per sq. in.	Elongation %.	Reduction of area %.	Elastic limit. Tons per sq. in.	Breaking load. Tons per sq. in.	Elongation %.	Reduction of area %.
A.	0·20	0·64	0·10	0·06	0·80	...	27	37	24	28	20	31	35	46
B.	0·16	0·61	0·10	0·07	1·04	0·53	27	38	29	43	22	31	34	47
C.	0·25	0·64	0·11	0·07	1·04	1·80	25	41	19	24	23	35	29	39
D.	0·38	1·21	0·14	0·07	0·65	2·50	38	52	15	15	27	43	14	24
E.	0·55	0·69	0·11	0·06	0·79	4·46	37	57	15	17	25	46	19	22
F.	0·52	0·75	0·14	0·06	0·79	6·91	*	55	14	13	30	44	22	25

* No set at 25, 30, 35.

The electrical resistance of two of the alloys as determined by Professor Barrett was as follows:—

Sample.	Electrical Conductivity.		Specific Resistance.
	Iron = 100.	Copper = 100.	
1209 C.	44·1	7·4	23·2
1209 F.	33·3	5·6	30·7

—**R. A. Hadfield,** *The Iron and Steel Metallurgist, Vol. VII, No. 1,* pp. 3-21.—*P. L.*

A New Charcoal Retort Plant.

THE retorts are formed of horizontal steel shells 46 ft. long, 3 ft. 6 ins. wide, and 8 ft. 4 ins. high. The shells, made from ⅝-in. plate, are set in and between brick walls, and the flues arranged to evenly distribute the heat around the retort. Each end of the retort is fitted with a double set of cast-iron doors, forming an air-tight seal, and a fire-grate, placed below one end. In a line with each retort coolers are placed, and through the whole standard gauge rails are laid. The wood for carbonisation is loaded on steel cars, three of which nearly fill a retort. On completion the cars pass into the first set of coolers, remaining there during the progress of a further conversion in the retort, and then passing into the second set of coolers. On emerging from the last set of coolers the charcoal, still on the cars in which it was carbonised, is hauled either to the blast furnaces or, if intended for shipment, to railway box-cars and "dumped." The gases of distillation are drawn away from the retorts and passed through condensers, and the condensible gases brought into liquid form as pyroligneous acid. The non-condensible gases are passed on to boilers and used for generating steam. The advantages of the process lie in its continuous character, in the small amount of manual labour required, and in the recovery of the valuable by-products.—**Ernst A. Sjöstedt,** *The Iron Age, Vol. LXXIII, No. 4,* pp. 16-18.—*P. L.*

The Heat Treatment of Steel.

THE object of the research embodied in the sixth report to the Alloys Research Committee was mainly to observe and record the change in properties which different varieties of steel undergo when submitted to thermal treatment. The material was tested under the following conditions: (1) As received; (2) annealed for half an hour at the following temperatures: 620 degs. Cent., 720 degs. Cent., 800 degs. Cent., 900 degs. Cent., and 1,100 degs. Cent.; (3) soaked for 12 hrs. at the temperatures given in No. 2; (4) quenched at the following temperatures in water: 720 degs. Cent., 800 degs. Cent., 900 degs. Cent., and 1,200 degs. Cent.; (5) Quenched in oil under the following conditions; (*a*) quenched at 720 degs. Cent. and not reheated, (*b*) quenched at 720 degs. Cent., 870 degs. Cent., and 1,000 degs. Cent. and afterwards reheated to 350 degs. Cent.; (*c*) quenched at 800 degs. Cent., 900 degs. Cent., and subsequently reheated to 600 degs. Cent. A micro-section was cut from each piece, and the bars then turned down into tensile test pieces. The results obtained from these tests are embodied in the following tables:—

Combination of

Carbon °/₀	Original Bars as received.			Bars Annealed for Half-an-hour.											
				620° C.			720° C.			800° C.			900° C.		
	Max. Stress. Tons.	Elongation °/₀	Reduction of Area °/₀	Maximum Stress	E °/₀	R A °/₀	Maximum Stress	E °/₀	R A °/₀	Maximum Stress	E °/₀	R A °/₀	Maximum Stress	E °/₀	R A °/₀
0·130 ...	30·22	20·00	34·73	...	...	...	20·16	44·50	73·26	20 10	46·20	71·16	21·48	45·00	71·16
0·180 ...	31·52	12·50	29·71	30·60	33·00	62·85	26·52	36·00	72·54	26·46	35 00	67·32	27·84	33·50	60·24
0·254 ...	33·25	12·70	25·31	34·50	24·00	55·03	28·80	32 50	62·66	29·40	29·50	58·56	29·46	32·50	54·84
0·468 ...	36·96	6·25	18·76	37·02	24 00	49·70	32·80	29·00	58·56	33·00	27·50	45·60	32·46	28·00	46·26
0·722 ...	49·00	11·72	3·43	50·22	20·50	33·48	39·96	23·00	47·88	42·48	17·70	31·74	43 20	16·50	25·86
0·871 ...	58·02	5·47	5·38	55·02	12·00	22·11	43·98	20·00	40·42	52·50	11·50	16·92	50·40	11·20	15·84
0·947 ...	53·74	7·03	5·63	52·90	15·00	27·00	39·30	22·00	45·00	39·96	18·00	28·44	51·12	10·00	15·42
1·306 ...	56·11	7·03	8·48	51·54	3·00	3·90	50·58	7·00	5·12	39·12	20·00	33·90	44·52	5·50	5·58

Combination of

Carbon °/₀	Quenched in Water at 20° C.												Quenched in Oil at 80° C. Not Tempered. 720° C.		
	720° C.			800° C.			900° C.			1,200° C.					
	Maximum Stress	E	R A	Maximum Stress	E	R A	Maximum Stress	E	R A	Maximum Stress	E	R A	Maximum Stress	E	R A
0·130	36·18	22·00	60·20	38·88	21·70	59·94	32·34	28·20	76·26	44·29	9·00	39·12	32·68	26·00	59·62
0·180	44·82	14·00	46·92	49·02	14·50	51·60	49·92	6·50	35·28	72·78	3·50	5·16	36·79	25·00	60·24
0·254	43·20	13·70	45·96	52·38	6·50	8·94	70·32	3 80	13·44	77·04	3·00	4·74	37·84	23·00	57·77
0·468	39·60	21·00	48·78	61·26	1·60	6·00	55·44	1·00	2·64	31·74	*Nil*	*Nil*	39·75	24·50	48·82
0·722	51·00	17·50	32·92	...	...	...	61·98	1·00	2·56	13·44	*Nil*	*Nil*	50·43	16·50	36·54
0·871	54·84	15·80	29·58	...	...	...	26·04	2·00	2·16	5·40	*Nil*	*Nil*	76·77	13·00	36·34
0·947	56·04	12·00	24·78	...	...	...	21·60	*Nil*	*Nil*	4·20	*Nil*	*Nil*	52·30	13·00	19·81
1·306	56·94	8·80	15·84	70·02	0·50	1·32	...	...	...	3·52	*Nil*	*Nil*	53·82	7·00	8·67

PRIME MOVERS.

On Cylinder Condensation and Valve Leakage in Steam Engines—*contd.*

WHEN the temperature across a metal wall does not diminish uniformly, as is the case in the cylinder wall of a steam-engine, we must plot the curves of temperature at different depths in the wall. The curves for several crank angles are shown in Fig. 1. We assume in all cases that the inside surface temperature is a maximum when the crank angle is 90 degs., angles being measured from the dead centre. To calculate the heat flowing across the metal at the lines *A* and *B*, *B* being at a depth $x = \frac{1}{32}$ in., we draw tangents to the temperature curve *a b c* at *a* and *b*, and by these measure the gradient of temperature at these points. At *a*, the gradient $i_1 = 126$ degs. per inch, and at *b*, $i_2 = 92$ degs. per inch, and therefore if $k = 5{\cdot}2$ we have $5{\cdot}2 \times 126 = 655{\cdot}2$ T.U. per sq. ft. per minute flowing across surface *A*. Heat is also flowing across surface *B* at the rate of $5{\cdot}2 \times 96 = 478{\cdot}4$ T.U. per sq. ft. per minute. Considering the slab of metal 1 sq. ft. in area and $\frac{1}{32}$ in. thick, we see that $(655{\cdot}2 - 478{\cdot}4) = 176{\cdot}8$ T.U. more heat flow into it per minute than flow out of it, and therefore if w = weight of 1 cub. ft. of cast-iron, and s is the specific heat; if v is the rise in temperature per minute, and if x is thickness in feet, we have $k(i_1 - i_2) = w\,s\,v\,x$ (4). In the particular case $v = 1{,}276$ degs. per minute. Equation (4) may be written $k\left(\frac{d^2v}{dx^2}\right) = w\,s\left(\frac{dv}{dt}\right)$ (5). This gives the rate at which the first $\frac{1}{32}$ in. of wall is rising in temperature when the crank angle is 45 degs. Assuming that this rate remains constant, while the crank moves from 0 degs. to 90 degs. (*i.e.* during half a second, if the revolutions be 30 per minute—the speed for which the curves were drawn), this slab of wall will have risen in temperature by $\frac{1{,}276}{120} = 10{\cdot}6$ degs. A more elaborate calculation is necessary to obtain a rigorously

Tables 21, 23 & 24.

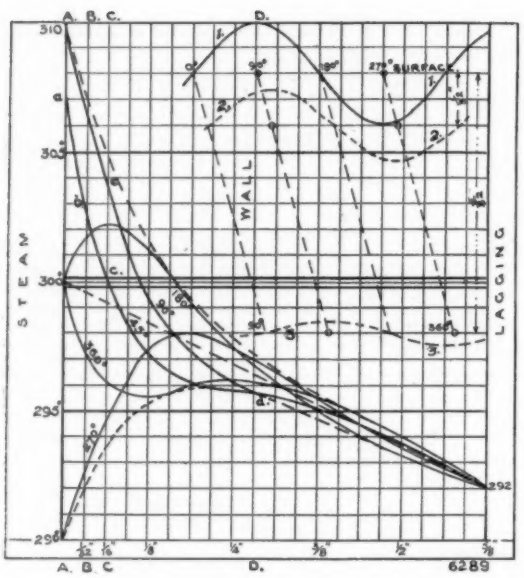
Bars annealed for half-an-hour.			Bars soaked for 12 hours.											
1,100° C.			620° C.			720° C.			900° C.			1,200° C.		
Maximum Stress.	E %	R A %	Maximum Stress.	E %	R A %	Maximum Stress.	E %	R A %	Maximum Stress.	E %	R A %	Maximum Stress.	E %	R A %
...	...	...	19·75	48·50	81·12	20·00	42·50	73·21	...	...	...	...	...	...
26·91	39·50	60·60	26·81	32·50	71·43	27·75	29·50	61·11	26·91	37·00	58·80	25·27	18·00	59·30
28·11	33·50	54·77	28·60	31·00	65·18	28·18	31·00	57·28	29·55	29·00	57·50	24·86	12·50	56·80
31·38	27·00	40·38	32·01	33·00	57·61	29·31	30·50	42·70	29·91	30·00	43·50	29·10	16·00	38·80
42·38	14·00	17·21	40·63	29·50	46·54	38·11	21·00	35·97	43·21	12·50	14·00	40·17	11·00	11·30
47·09	11·00	12·51	45·25	19·50	30·82	39·38	19·50	29·69	49·32	11·00	15·30	29·55	20·00	40·20
49·62	7·50	9·07	45·41	18·50	27·10	33·73	23·50	35·44	47·76	11·90	11·00	24·02	20·00	37·50
46·62	6·50	8·94	46·96	11·50	16·45	33·38	26·50	34·50	44·41	10·00	11·70	35·93	33·00	21·70

Tables 25, 27 & 28.

Quenched in Oil at 80° C.														
Tempered at 350° C.									Tempered at 600° C.					
720° C.			870° C.			1,000° C.			800° C.			900° C.		
Maximum Stress.	E	R A	Maximum Stress.	E	R A	Maximum Stress.	E	R A	Maximum Stress.	E	R A	Maximum Stress.	E	R A
22·13	41·00	75·91	24·50	39·50	76·44	25·91	32·50	67·48	21·42	38·00	70·60	24·55	40·70	72·00
31·10	29·00	59·88	36·12	23·50	65·38	35·96	26·50	63·04	36·16	26·00	57·00	30·13	30·00	58·50
34·15	25·00	57·87	41·13	24·50	62·14	40·32	19·00	60·51	...	...	...	31·24	26·20	58·40
41·83	20·00	50·12	54·65	25·00	47·17	54·10	14·00	63·59	41·06	17·00	52·30	35·71	27·20	51·00
48·70	21 50	36·00	78·59	23·50	38·08	76·41	14·00	32·69	58·47	17·50	38·90	50·44	17·50	33·30
53·9	13·50	27·63	90·68	10·50	31·82	83·84	9·50	24·15	53·11	15·00	32·60	52·68	15·50	30·00
54·63	12·00	18·64	102·52	7·00	16·99	94·19	5·50	14·84	45·97	12·00	12·90	49·10	17 00	28·00
57·75	6·50	...	90·57	5·50	10·57	90·00	5·00	7·09	46·86	7·50	22·00	51·32	17·60	21·00

Sixth Report to the Alloys Research Committee, Proc. Inst. Mech. Engineers, Jan., 1904.—P. L.

correct solution, which is rather less than 10 degs. These curves then enable us to estimate the rate at which heat is being given to the wall by the steam, and so at what rate steam is being condensed to supply this heat. The shape of the temperature curves will depend on:—1. The way in which the steam periodically varies its temperature. 2. The law according to which it parts with its heat to the metal. We may obtain the first law by drawing a diagram of the temperatures of the steam, on a base of crank angles, through one revolution. It was found that the assumption of a simple harmonic law of temperature variation, fit the case fairly well, and if v = temperature of wall surface, at any time "t" measured in minutes from the beginning of the stroke, when crank angle is $\propto$, V_0 = mean temperature of surface; $2A$ = range of surface temperature in degrees; N = number of revolutions of engine per minute, this curve, illustrated in upper part of Fig. 1, is $V = V_0 + A \sin 2\pi N t = V_0 + A \sin \propto$ (6). The variation of temperature at any depth x is a similar curve, of smaller range and retarded in time. Curve 22 gives temperature range at a depth of $\frac{1}{12}$ in. and curve 3·3 at $\frac{3}{12}$ in. Ratio of range at depth x to that at surface is e^{-mx} where $m = \sqrt{\frac{\pi N w s}{k}}$. The crest of this diminished temperature wave, reaches the depth x at the time $\frac{mx}{2\pi}$ of a revolution, later than when temperature is maximum at the surface. Thus temperature at any depth, for any crank angle is $V = V_0 + A e^{-mx} \cdot \sin (\propto - mx)$ (7). The temperature curves given were calculated from the formula $V = V_0 + A e^{-mx} \sin (\propto - mx) \mp px$, the term px being added to allow for external radiation or jacketing. The temperature depth curves can be deduced from



ON CYLINDER CONDENSATION AND VALVE LEAKAGE IN STEAM ENGINES.

the temperature time waves in Fig. 1. When the depth is such that the crest of the wave of temperature has lagged behind that at the surface by one wave length ($m x = 2\pi$), the range of temperature is about 0·08 degs. Fahr., for a surface range of 20 degs. Fahr. This depth is ·7 ins. for a speed of 30 revolutions per minute, being equal to $\left(\frac{2\pi}{m}\right)$. At 100, 200 and 300 revolutions the depths are 0·388 ins., 0·275 ins., and 0·224 ins. respectively, so that at these depths the temperature fluctuations die out.—**Prof. J. T. Nicolson, D.Sc., M.I.C.E.,** *Power, Vol. XXIII, No. 12.—A. H. G.*

The Forms of Turbines most suitable for Low Falls.

THE author draws attention in the first instance to the character of water-powers with low falls. These are seldom constant, and in most cases both the fall and the water supply vary. The variations present a difficulty to the proper utilisation of such power, which however can be surmounted. The prejudice against the utilisation of water-power with low falls, which constitute the majority of water-powers of the British Isles, arises principally out of the disregard of their peculiarities and the want of knowledge of the results which may be obtained from a specially adapted turbine under varying conditions, and is traceable to many unsatisfactory installations of absolutely unsuitable turbines. The paper then considers the difference between impulse turbines and pressure turbines, showing by a diagram that varying the portion of the fall used for producing pressure, that is, varying the degree of re-action, affords a means of adapting turbines to special requirements. Pure impulse turbines are not altogether condemned for low falls, but places in which they are preferable to pressure turbines are extremely few in this country, and even the Haenel turbine, which is an intermediate type between the two, is not often suitable. An instance is given in order to show that such turbines, though excellent in themselves and efficient, do not necessarily make a satisfactory installation. The manner in which the disadvantage of all axial-flow turbines, namely, the influence of the angles of vanes varying with the radial width, which is particularly serious in impulse turbines, is partially overcome, is then explained. The parallel-flow pressure turbine, generally known as the Jonval turbine, is mentioned as particularly adapted to greatly fluctuating falls, under which a constant speed may be obtained without sacrifice of efficiency. Such a turbine is described, which the author has installed for a fall of 2 ft., and particulars of tests, made with similar turbines at the Zürich Waterworks, are given, to show that the part-gate efficiency of parallel-flow pressure turbines of this kind is extremely good. It is characteristic of the large majority of re-action or pressure turbines that their part-gate efficiency is low, particularly so at less than half-gate, which renders them valueless for varying conditions; but as in Europe the water powers to be dealt with are chiefly of this kind, some European turbine-builders have succeeded in designing pressure turbines which are giving a very satisfactory efficiency even at quarter-gate. The demands of the generation of electricity by water-power, such as high speed, rapid regulation, and concentration of large power in one unit, have influenced very considerably the art of building turbines. In the first place, the desire for high speeds has led to a more general adoption of radial-flow turbines, of which the inward-flow type is preferable, being the more efficient. An example of radial-outward-flow turbines is cited, giving the special reasons which have led to their adoption in one case of a relatively low fall, and the manner in which a quite satisfactory efficiency was obtained from this otherwise less efficient type. One new type—the cone turbine—is referred to as taking the place of the so-called "mixed-flow turbines," with a view to obtain a high speed under low falls, even for large units. One important factor in turbines is the construction of the gate, and it is shown in

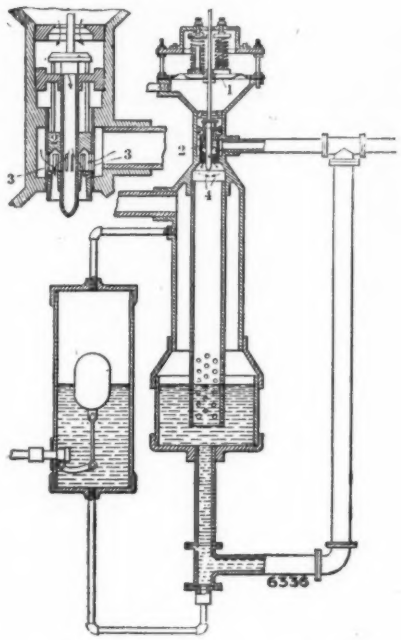


FIG. 1.—EFFICIENCY OF COMBUSTION MOTOR.

the paper that a distinction must be drawn between gates intended for adjustment of the turbine to a varying load, where a high part-gate efficiency is of less importance than rapid regulation, and gates for adapting a turbine to varying conditions, where a good part-gate efficiency is an essential condition. Next, with special regard to electrical requirements, reference is made to the arrangement of several wheels on one common turbine-shaft, vertical or horizontal, giving a few instances of the vertical arrangement which, under certain circumstances, is particularly advantageous, as the weight revolving on the footstep can be entirely balanced, and so the loss of power by friction is reduced almost to nil. The necessity of placing the footstep of a turbine in an accessible position is alluded to, and the two kinds of overhead footsteps most commonly used are illustrated. The paper concludes by drawing attention to the necessity of studying more closely the conditions of water-powers with low falls, and of paying greater attention to more careful adaptation of turbines to such falls, which would probably lead to a better appreciation of the water-powers of this country.—**A. Steiger, M.Inst.C.E.,** *Proc. Inst. Civil Engrs., Feb. 1904.*

Lines of Progress in the Efficiency of the Combustion Motor.

AT present it appears probable that the prime mover of the future will be either the steam turbo-generator or the internal combustion engine, each of which possesses a certain series of commanding merits, which, however, seem inseparably associated with equally prominent faults; the turbine, the ideal of mechanical simplicity, being grievously handicapped by its adjunct, the steam boiler, while the oil or gas engine presents all the limiting mechanical features of the reciprocating steam engine. If the thermal advantages of the gas engine could be combined with the mechanical advantages of the turbine, the result would certainly be the prime mover of the future. The first step towards this is to produce a constant pressure internal-combustion generator, and Fig. 1 represents an apparatus for burning liquid fuel continuously in connection with a water compartment, through which the gases of combustion were passed in order to suitably reduce the temperature before using in a cylinder. The

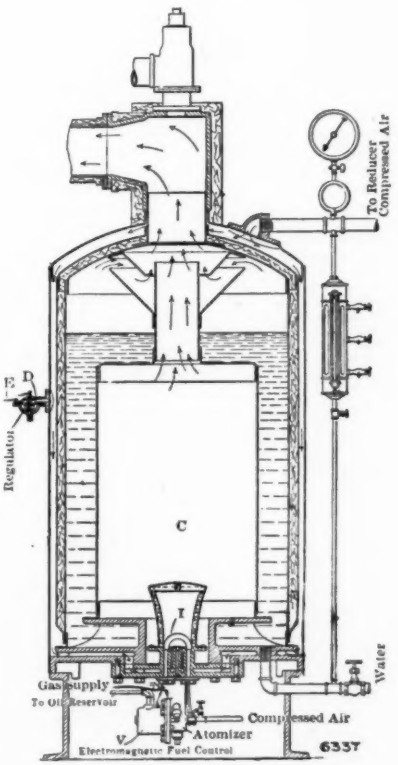


FIG. 2.—EFFICIENCY OF COMBUSTION MOTOR.

difficulty of governing the relative proportions of oil and air at varying loads prevented this being a success. Fig. 2 shows a pressure generator for liquid fuel, designed by the author, kerosene oil being injected into the combustion chamber and atomised by means of a compressed-air supply, maintained by a pump, at a pressure about 20 lbs. above the pressure in the apparatus. Ignition is accomplished by the internally-fired porcelain tube *I*. The combustion chamber is surrounded by a water chamber, with which it is in free communication, and part of the heat evolved by combustion will be used in forming steam in this chamber. This steam will mix with the gases of combustion, the whole being reduced to a temperature suitable for use in a rotary engine. Regulation of pressure is secured by interrupting wholly the flow of oil, by the magnetically actuated valve *V*, the pressure diaphragm *D* operating to interrupt the electrical circuit *E* on a rise of working pressure, thus allowing a spring to close the oil valve. This arrangement insures against any variation in the composition of the mixture, which might produce imperfect combustion. The water level in steam compartment may be maintained automatically, or may be regulated as is the feed in steam boilers, Since the only losses in the apparatus are those due to radiation, it would appear that an economy considerably greater than that due to the best gas-engines, can be obtained by using this generator with an efficient rotary engine.—**Edward C. Warren,** *Eng. Mag., Vol. XXVI, No. 5,* pp. 664-673.—*A. H. G.*

The Pielock Superheater System.

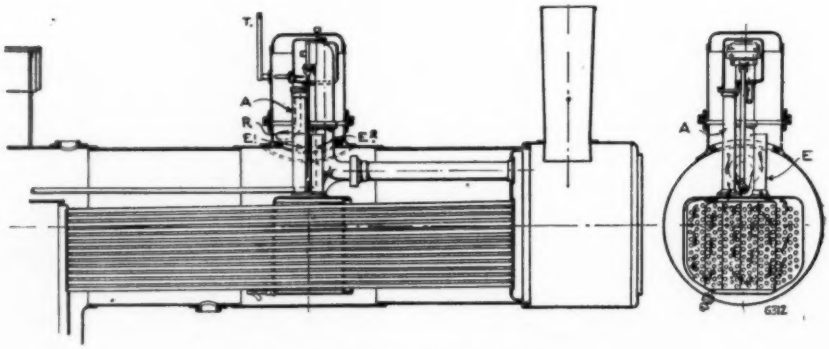
THE Pielock superheater, just brought out by the Hannoverscher Maschinenbau A. G. vorm. Georg Egestorff, Linden, near Hanover, is remarkable for its simplicity and arrangement of its parts, in addition to its low cost. This superheater is designed not only for locomotive, but for other types of boilers; and can be readily fitted in not only new, but in existing boilers. The superheater, as arranged for use in a locomotive, consists mainly of a box surrounding the existing tube system in the boiler. This box is divided by partition walls into different compartments, this insuring a contact as prolonged and as intimate as possible between the steam and the heating tubes. The steam, after entering the superheater box at boiler pressure through the inlets E_1 and E_2, traverses the various compartments in the direction of the arrows, and enters through the tube *A* the dome. The temperature of the superheated steam is indicated by a thermometer *T*, provided with big figures, so as to be easily read from the driver's cab. A tube, *R*, leading from the governor through the dome base, serves to supply superheated steam to the air-pump, as well as for cleaning the rails, heating, etc. Experiments so far made on the Pielock superheater have fully borne out the hopes attached to the same. In connection with experiments made on behalf of the Prussian railway authorities, a saving of coal as high as 15 per cent., and of water as high as 18 per cent., was stated, as compared with locomotives using saturated steam. In virtue of the reduced space occupied by the superheater any desired temperature up to the maximum of 300 to 350 degs. may be obtained, according to the position and length of the apparatus. — **Prof. M. Buhle,** *Dingler's Polyt. Journal, Vol. CCCXIX, No. 1,* pp. 1-4.—*A. G.*

Comparison of Different Types of Calorimeter.

THE differences between the results obtained in finding the calorific value of fuel by means of different types of calorimeters, make it difficult to put confidence in such determinations. The authors, recognising this, made a series of tests with the Lewis Thompson, William Thompson, Fischer, and Mahler calorimeters, to determine the degree of coincidence between the results obtained. They also calculated the calorific value of the coal from the formula $Q = \frac{1}{100}$

$$\left[8{,}140\ C + 34500\left(H - \frac{(O + N) - 1}{8}\right) + 2220\ S\right]$$

where Q = calorific value in thermal units, and



ARRANGEMENT OF THE PIELOCK SUPERHEATER.

where C, H, O, N, and S represent the percentages of carbon, hydrogen, oxygen, nitrogen, and sulphur, in the coal. The following tables summarise the results obtained :—

	Coal.	Lewis Thompson (Corrected).	William Thompson.	Fischer.	Mahler (Bomb).
A	Mean	8418	8284	8139	8629
	Highest	8602	8490	8172·5	8639
	Lowest	8082	8129	8090	8613
	Per cent. error	6·4	4·4	1·0	0·3
B	Mean	7235	7178	7509	7713
	Highest	7436	7303·5	7561	7727
	Lowest	7029	7090·5	7465·5	7706
	Per cent. error	5·8	3·0	1·27	0·27
C	Mean	8331	8324	8243	8617
	Highest	8442·5	8425	8287·5	8631
	Lowest	8173	8162	8187	8606
	Per cent. error	3·1	3·2	1·2	0·3
D	Mean	8144	8233	8049·7	8394·5
	Highest	8250	8304	8087·5	8402·5
	Lowest	8063	8156	8007·5	8389·0
	Per cent. error	2·3	1·8	1·0	0·16
E	Mean	8178	7882	7627	8026·5
	Highest	8316	7997	7648	8037
	Lowest	7997	7755	7598	8018
	Per cent. error	3·9	3·1	0·6	0·24

Analysis of Coals (dry), and Calculated Values.

Coal	C.	H.	S.	Ash.	O+N.	Fixed Carbon.	Volatile Matter.	Calorific Values. Calculated.	Calorific Values. Determined.	Per cent. low of Calculation.
A	90·09	3·85	0·77	1·68	3·61	91·48	6·84	8567	8629	0·7
B	81·02	3·23	0·64	9·50	5·61	80·80	9·70	7527	7713	2·4
C	87·79	4·09	0·59	3·14	4·39	82·79	14·08	8425	8617	2·2
D	84·07	4·51	0·685	5·69	5·045	73·81	20·50	8241	8394·5	1·8
E	78·29	4·76	1·48	14·90	10·57	61·10	34·00	7638	8026·5	4·8

The authors come to the conclusion that the Lewis Thompson calorimeter—the only one relying on a solid oxidising material—gives the largest error, due to incomplete combustion ; and that the bomb calorimeter shows a marked superiority to all others.

—J. S. S. Brame *and* **Wallace Cowan,** *Jnl. Soc. Chemical Industry, Vol. XXII, No. 22,* pp. 1230–1233.—*A. H. G.*

The Voght Gas Engine.

This is an engine introducing a radical change in explosion-engine design, in substituting for the water jacket a piston with an hydraulic cushion, and is the joint invention of Adolp Voght and Recklinghausen. It consists of a horizontal double-acting cylinder with a vertical extension-chamber at each end of about twice the capacity of the sweep of the piston ; both these uptakes terminate in explosion chambers with igniters and controlling valves. The most notable feature is the absence of the water jacket, the cylinder and chambers being supplied with water, over which the explosive action takes place and actuates a double-acting piston. In the small model of less than two h.p., recently tested in London by Prof. Capper, a surprising economy has been attained ; this result is attributed to the high degree of compression used, to a perfectly shaped explosion chamber, and to water sealing of all parts exposed to the hot gases. In the illustration Fig. 1, C is a double-acting cylinder ; B^1 and B^2 water extension chambers, over which are situated explosion chambers X, X ; A, A are compressed-air inlets ; E, E, exhaust outlets ; G, G, compressed-gas inlets ; all

provided with mechanically operated lift valves. The engine works on the two-cycle period, and transmits the power of two-impulse strokes to the crank at each revolution. The engine is governed by delaying the closing of the exhaust valves and the opening of the gas valves, thus allowing more or less of the air charge to escape; a corresponding less amount of gas being admitted to form a mixture of constant quality. Constant compression is maintained at all loads and for varying volumes of mixture by the flow of water through the operated valves K, K' and spring-loaded valve L. This is performed in an automatic manner by the balancing action of water under pressure that controls the capacity of the explosion chambers in correspondence with the volume of explosive mixture supplied for compression at each stroke. The power cylinder of this interesting model is a little over 3 ins. diam. by 6 ins. stroke, and is supplied by air under about 3 lbs. pressure by a double-acting tandem air-pump, of a capacity 1½ times greater than the power cylinder, and is actuated by the tail-rod R; compressed gas at about 16 lbs. pressure is supplied by a smaller cylinder operated by a separate crank. The governing action is clearly illustrated by the three diagrams on Fig. 2, on which the full line represents an overload, the chain line a working load, and the dotted line a light load diagram. At all loads the exhaust commences with the crank at a, corresponding to the points 7, 7, 7 on the diagrams, and closes at the points 3, 3, 3 on the atmospheric line b, b; compression then commences and is immediately followed by the admission of gas under pressure for a period up to 18 degs., according to the load, and is indicated by the points 4, 4, 4. Highest compression is at 5 at all loads, and highest explosion pressures at 6, 6, 6. The capacity of the explosion chambers for the three diagrams is indicated by v^1, v^2, v^3, and the zero line by 1, 1. The advantages claimed for this engine are water sealing and cooling of the piston, air and exhaust valves; minimum loss through leakage and unequal expansion; avoidance of oil lubrication for the cylinder; less heat waste through conduction and radiation; absence of the water jacket; constant compression at all loads; governing by variable volume; automatic super-saturation of the mixture, permitting higher compression than by other means; perfect scavenging of the explosion chambers; engine capable of working most economically at one-fourth under full load; no necessity for periodical cleaning out furnace-gas dust deposits from the cylinder. Against this may be mentioned the possibility of water agitation through the churning action of the piston, unless limited to a very slow speed; great reciprocating mass to be balanced; increased frictional resistance

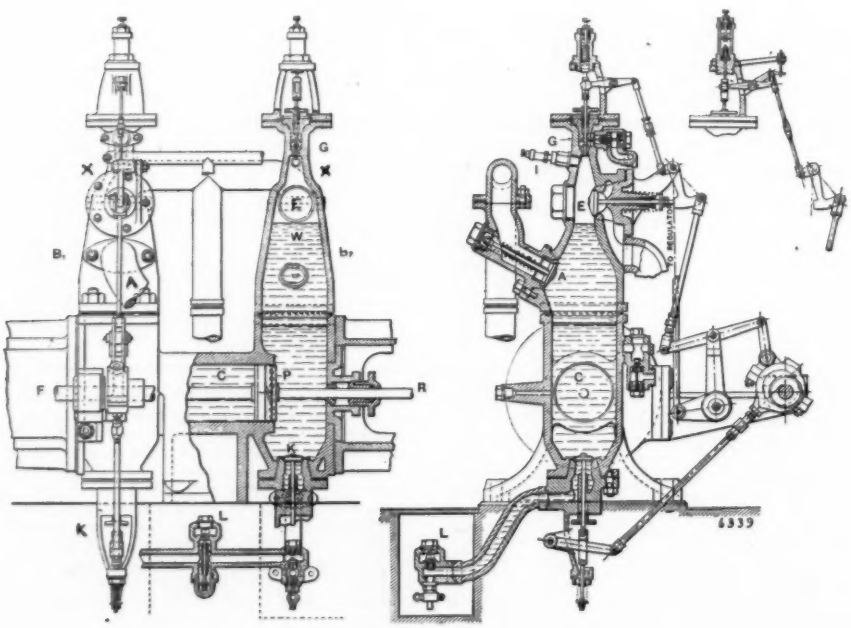


FIG. 1.—THE VOGHT GAS ENGINE.

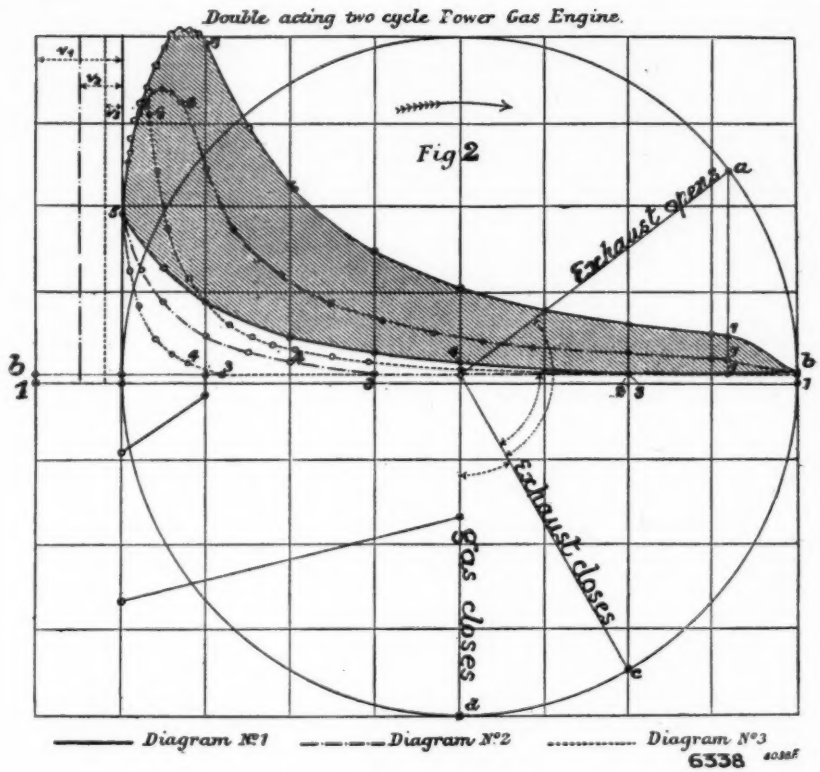


FIG. 2.—THE VOGHT GAS ENGINE.

of the water-cushioned piston, etc. To settle some of these points a much larger engine is to be built.—**H. A. Humphrey, M.I.C.E., etc.,** *Engg., Vol. LXXVII, No. 2.—E. B.*

NAVAL ARCHITECTURE.

Shipyard Economies.

THE problem of shipyard economies is dealt with in a very able and comprehensive manner, dealing as it does with the various sections and sub-sections upon which depend the successful organisation of shipbuilding work. After enumerating the existing conditions of American shipbuilding, the author goes on to say that, setting aside the problems connected with design and market prices as being beyond the range of the present discussion, the practicable economies of ship construction can be roughly classified for consideration as follows: Labour, Labour Control, Organisation, Plant and Materials. Each of these sections is again further sub-divided in a manner so as to indicate the features to be kept in view for possible economising. The employment of unskilled or cheap labour upon all jobs not necessitating skilled operation is a first principle of economy, and requires tact and resolution to put into practice, and also keen observation and practical knowledge for the discovery of opportunities. The following are a few illustrations of cases in which this economy has been, or might be, effected. All material prepared in the mill or shops may be transported to vessels under construction by unskilled labour, with or without the aid of mechanical transport. Under-foremen do not always realise that in such ways as this their men may often be conscientiously attending to their work while they are wasting time and money. The whole of the structural ironwork of a ship can be first and second coated with paint by unskilled men, and almost 50 per cent. of finishing work done by the same labour. A great deal of work, such as laying launching ways, moving shores and

ribbands, erecting uprights, getting up beams and frames, could be done by gangs made up of a mixture of skilled and unskilled labour in the ratio of about 2 to 5, and will then actually turn out more work per man. In view of the possible combination of mould-and-template system of construction, while those portions of the structure which require furnacing can be most successfully accomplished by skilled workmen using their own templates, all straight work could be undertaken by cheap or partially-skilled labour working from moulds. The reduction of the employment of skilled labour to a minimum is rather more than a mere complement of the preceding, because, apart from the fact that a skilled workman is not required to do work which can be accomplished by an unskilled man, the problem is involved of reducing, as far as possible, the number of operations which can only be carried out by skilled labour. For example, the modern practice of employing steel and other castings for purposes formerly served by blacksmith and anglesmith work, the whole subject of the employment of power driven, and automatic tools and labour-saving devices, as well as considerations of finish and detail designs, have for their object the attainments of economy in this direction. The need for efficient supervision to prevent loafing, efficient organization of work to prevent loss of time due to distances to be traversed, and the conditions under which the employees are compelled to work, are pointed out as items which greatly affect the work's economy. Excepting under special circumstances the adoption of overtime is discountenanced, for, as the author points out, increased rates of wages have to be paid, whilst the output of a workman during the last 3 hrs. of a 13-hr. day is almost invariably reduced. Means suggested by which overtime may be limited are the placing of orders for materials at the earliest possible date, securing well-timed deliveries, commencing construction as soon as it can be proceeded with continuously. It is pointed out that night-shift work is more economical than overtime, when the work in hand exceeds the daily capacity of the machine tools, and in some instances it is distinctly more economical to resort to this than to sink further capital in plant. The adoption of piecework has proved a source of some difficulty, particularly in the iron department of some firms. Improvements in plants are made, and the men's power of production thereby increased. Certain reductions in prices paid now appear reasonable, but are strongly resented by the men, and compromise is often the result. Good results have been shown in machine shops from the working of a premium system grafted on to an existing time wage system. The following suggest themselves as possible fields for the introduction of this system: Shop-joiner work, fitting up state-rooms and store-rooms in merchant vessels, fitting up shell-rooms, magazines, etc., on warships, ship-fitting, anglesmith work and blacksmith work. Regarding labour control, proportioning the numbers and timing the operations of the various gangs of men so as to prevent delays, is a most important matter. When a firm is doing work of a more or less settled type, the records of a previous vessel will provide very useful information for a succeeding one if properly kept. As an example of one method by which this may be effected, the machinist labour on a battleship was daily reported under the following sections: (*a*) Pumping, draining, flooding, and ventilation; (*b*) Turret, casemate, gun and ammunition-hoist fittings; (*c*) Watertight and airtight doors, shutters and manholes, and gearing up to main deck; (*d*) Hatchways, shutters, skylights, etc., above main deck, and general ship fittings; (*e*) Shopwork. Arranging the work so that progress made by one gang or individual workmen can be checked off against that made by others gives the men incentive for competition. Laying wood decks and hold ceilings, finishing state-rooms, water-testing compartments, fitting watertight and other doors, shutters and hatches, and fitting launching ways and jacking are some examples of work which may thus be arranged. Under-foremen and leading men must be carefully selected, and be kept thoroughly informed by plans, lists, and daily notes.—**R. S. Hubbard,** *Marine Engg., Vol. IX, No. 1*, pp. 12–15.—*(To be continued.)—H. B. D.*